STRATIFICATION OF SOUTHERN GEORGIA STREAMS FOR RAPID BIOASSESSMENT FOCUSING ON DIFFERENCES IN STRUCTURE AND FUNCTION OF BLACK WATER AND CLEAR WATER STREAMS

Salini Pradeep Pillai

Columbus State University

The College of Science

The Graduate Program in Environmental Science

Stratification Of Southern Georgia Streams For Rapid Bioassessment Focusing On Differences In Structure And Function Of Black water And Clear water Streams.

A Thesis in

Environmental Science

By

Salini Pradeep Pillai

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

February 2007

Columbus State University

The College of Science

The Graduate Program in Environmental Science

Stratification Of Southern Georgia Streams For Rapid Bioassessment Focusing On Differences In Structure And Function Of Black water And Clear water Streams.

A Thesis in

Environmental Science

By

Salini Pradeep Pillai

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

February 2007

I have submitted this thesis in partial fulfillment of the requirements for the degree of Master of Science.

3/26/07

Date

Salini

Salini Pradeep Pillai

We approve the thesis of Salini Pradeep Pillai as presented here.

28 March 2007

Date

James A Gore

James Arnold Gore, Department Chair of Environmental Science Policy & Geography

30 March 2007

Date

George E. Stanton, Vice President for Academic affairs

April 2, 07

Date

Thomas Hanley, Department Chair of Chemistry and Geology

ABSTRACT

As part of a rapid bioassessment project for the state of Georgia, relatively unimpaired reference streams and impaired sites were sampled for biological, chemical and physical parameters, and macroinvertebrates were identified. The metrics, biological, physical and chemical metrics, were selected using Ecological Data Application System Version 3.3.2k (EDAS). Discrimination efficiency and correlations were performed to determine the best metrics that separated impaired streams from reference streams and later on to form the index of stream water quality. Principal components analysis of the selected metrics showed that some of the blackwater reference streams and clearwater reference streams are randomly placed over the ordination space and a few of the black water reference streams and a few of the clear water reference streams formed distinct clusters. As a result, the black water and clear water streams were analyzed as two different stream types. In Southern coastal plain ecoregion the compositional metrics are the dominant forms of metrics in streams. When the blackwater streams and clearwater streams were analyzed as two different stream types, different macroinvertebrate metrics characterized blackwater and clearwater streams within the two ecoregions. The metrics that formed the indices were more efficient in discriminating impaired and reference streams when separated into the two stream types. Index values were higher; demonstrating the better performance of the metrics. The percentage of reference streams' in excellent condition is higher in independent analysis. It can be concluded that within the constraints of RBP; metrics were able to distinguish slightly the two stream types, which in turn proved the requirement of a different set of reference criteria, and a different stress response for the metrics of both stream types, that will enhance the results and in turn the judgment.

TABLE OF CONTENTS

ABSTRACT..iii

LIST OF FIGURES..iv

LIST OF TABLES..viii

INTRODUCTION..1

METHODS AND MATERIALS..13

Metric selection..20
Index development..25
Data analysis..25

RESULTS..28

Chemical and Physical Data Analysis of Reference Streams.........28
Habitat Score Analysis of Reference Streams........................31
Wolman Pebble count Analysis of Reference Streams...............32

Comparing the abundant macroinvertebrates in the blackwater and clearwater streams of the southeastern plain ecoregion and Southern coastal plain ecoregions.. 34

ANALYSIS

Southern coastal plain ecoregion streams (ecoregion 75)..............37
Southern Coastal Plain (ecoregion 75) blackwater streams..........42
Southern Coastal Plain (ecoregion 75) clearwater streams...........45
The Southeastern Plain streams (ecoregion 65).......................50
The Southeastern Plain (65 ecoregion) blackwater streams......... 55
The Southeastern Plain (65 ecoregion) clearwater streams......... .67

DISCUSSION..73

CONCLUSION..89

REFERENCES CITED..92

APPENDIX A: Chemistry Data..105

APPENDIX B: Southern coastal plain streams - Metrics with Discrimination Efficiency of 50% and above..106

APPENDIX C: Southern coastal plain ecoregion (75) - Standardized Metrics and Final Index..107

APPENDIX D: Southern coastal plain Blackwater streams (Ecoregion 75) – Metrics with Discrimination Efficiency 50% and Above……………………………..……108

APPENDIX E: Southern coastal plain Blackwater streams (Ecoregion75) -Standardized Metrics and Final Index…………………………………………………..109

APPENDIX F: Southern coastal plain Clearwater streams (Ecoregion 75) - Metrics with Discrimination efficiency of 50% and above……..............................110

APPENDIX G: Southern coastal plain Clearwater streams (Ecoregion 75)- Standardized Metrics and Final Index……………………………………………………112

APPENDIX H: Revitalized metrics- Ecoregion 75……………………………………114

APPENDIX I: Southeastern plain streams (Ecoregion 65)- Metrics with a DE of 50%and Above…………………………………………………………………………115

APPENDIX J: Southeastern plain streams (Ecoregion 65) –Standardized Metrics and Final Index……………………………………………………………………..…119

APPENDIX K: Southeastern plain blackwater streams (Ecoregion 65) with a DE of 50% and above………………………………..……………………….…......123

APPENDIX L: Southeastern plain blackwater streams (Ecoregion 65) - Standardized Metrics and Final Index……………………………………………….......127

APPENDIX M: Southeastern plain clearwater streams (Ecoregion 65) - Metrics with a DE of 50% and Above…………………………………………………......131

APPENDIX N: Southeastern plain clearwater streams (Ecoregion 65)—Standardized Metrics and Final Index…………………………………………………....133

APPENDIX O: Ecoregion 65 – Revitalized metrics…………………………………..135

LIST OF FIGURES

1. Level III and IV Ecoregions of Georgia..15

2. Dendrogram analysis of chemical and physical conditions of southeastern plain streams. Blackwater streams are designated as "-b" and clearwater streams are designated as "-c.. 30

3. Dendrogram analysis of chemical and physical conditions of southern coastal plain streams. Blackwater streams are designated as "-b" and clearwater streams are designated as "-c"..31

4. Index discriminating reference and impaired sites (Southern Coastal Plains – Ecoregion75).. 41

5. Index discriminating reference streams and impaired blackwater streams (Southern Coastal Plains Ecoregion 75) 45

6. Index discriminating reference streams and impaired clearwater streams for the Southern Coastal Plains(Ecoregion75)............................... 48

7. Principal Components Analysis of benthic metrics for the Southern Coastal Plains (Ecoregion 75) reference streams...49

8. Macroinvertebrate Index discriminating all reference and impaired streams in the Southern Plains (Ecoregion 65).. 54

9. Scatter plot showing the relationship between EPT Taxa and Clinger Taxa in southern plains blackwater streams (Ecoregion 65)............................. 58

10. Scatter plot showing the relationship between EPT Taxa and Trichoptera Taxa from blackwater streams is the southern plains (Ecoregion 65)...............................59

11. Scatter plot showing the relationship between Clinger Taxa and Trichoptera Taxa for blackwater streams of the southern plains (Ecoregion 65)...............................60

12. Scatter plot showing the relationship between Evenness and Dominants in common (individuals in one abundant taxa) 61

13. Scatter plot showing the relationship between Predator taxa and Percent Predators for blackwater streams of the southern plains (Ecoregion 65)...................... 62

14. Scatter plot showing the relationship between Evenness and Percent contribution of dominant taxon. 63

15. Scatter plot showing the relationship between Dominants in common (individuals in one abundant taxa) and Percent contribution of single dominant taxon for blackwater streams in the southern plains (Ecoregion 65)..................... 64

16. Index differentiating impaired streams and reference blackwater streams in the southern plains (Ecoregion 65)... 67

17. Index differentiating reference and impaired clearwater streams in the southeastern plain (Ecoregion 65).. 71

18. PCA ordination showing clusters of clearwater and blackwater reference streams in the southeastern plain(Ecoregion 65)... ... .72

19. Southern coastal plain (ecoregion 65) clearwater impaired and reference streams narrative ratings – a comparison...76

20. Pie chart showing percentage of southern coastal plain (ecoregion 65) clearwater reference streams classified by the final macroinvertebrate index in each category..77

21. Pie chart showing Percentage of Southern coastal plain (ecoregion 75) reference streams classified by the final macroinvertebrate index in each category..77

22. Southern coastal plain (Ecoregion 75) blackwater impaired and reference streams narrative ratings (using a blackwater-specific macroinvertebrate index) –a comparison...79

23. Pie chart showing Percentage of Southern coastal plain (Ecoregion 75) blackwater reference streams in each category when classified using a blackwater-specific macroinvertebrate index...79

24. Southeastern plain clearwater impaired and reference streams narrative ratings –a comparison...82

25. Pie chart showing Percentage of Southeastern plain (Ecoregion 65) reference streams in each category.. 82

26. Pie chart showing Percentage of Southeastern plain (Ecoregion 65) clearwater reference streams in each category...83

27. Southeastern plain (Ecoregion 65) blackwater impaired and reference streams narrative ratings using the blackwater macroinvertebrate index – a comparison...85

28. Pie chart showing Percentage of Southeastern plain (Ecoregion 65) blackwater reference streams in each category using the blackwater macroinvertebrate index..85

LIST OF TABLES

Table 1.1: Criteria for selection of stream reference sites in the southeastern U.S (Olson 2000..13

Table 1.2: Descriptions of Georgia Ecoregions. Data for elevation and slope represent the range for ± 5 Standard deviations from the mean..16

Table 1.3: Alphanumeric designations for candidate reference sites in Georgia from which biological, physical habitat and field chemistry were sampled (QAPP 2002)..16

Table 1.4: Criteria for selection of stream impaired stream sites in the southeastern U.S..17

Table 1.5: Definitions of best candidate benthic metrics and predicted direction of metric response to increasing perturbation (compiled from DeShon 1995, Barbour et al.1996, Fore *etal.*1996, Smith&Voshell 1997)..............................21

Table 1.6: Southeastern plain ecoregion blackwater reference and clearwater reference streams showing difference in pH, alkalinity and hardness.....................28

Table 1.7: Southern coastal plain blackwater reference and clearwater reference streams showing difference in pH, alkalinity and hardness..............................29

Table 1.8: Total habitat score (visual habitat assessment) for blackwater and clearwater reference streams of southeastern plain ecoregion.............................31

Table 1.9: Total habitat score visual habitat assessment) for blackwater and clearwater reference streams of southern coastal plains ecoregion...........................32

Table 2.0: Wolman pebble count of southeastern plain blackwater streams 32

Table 2.1: Wolman Pebble count of southeastern plains clearwater streams...............33

Table 2.2: Wolman Pebble count of southern coastal plain blackwater streams...........33

Table 2.3: Wolman Pebble count of southern coastal plain clearwater streams............34

Table 2.4: Abundant taxa in the southeastern plain blackwater and clearwater reference streams..35

Table 2.5: Taxonomic composition of southern coastal plain blackwater and clearwater reference streams..36

Table 2.6: Metrics and the corresponding discrimination efficiency of southern coastal plain streams..38

Table 2.7: Pearson product correlation for southerncoastal plain all streams............38

Table 2.8: The metrics that are to be candidates for inclusion in the final index for the southeastern coastalplain reference streams.......................................39

Table 2.9: Southern coastal plain streams (Ecoregion 75) – macroinvertebrate index Southern coastalplain streams- index..39

Table 3.0: Metrics and their corresponding discrimination efficiency of the southern coastal plain (ecoregion 75) blackwater streams 42

Table 3.1: Pearson product correlation for southern coastal plain ecoregion (Ecoregion 75) blackwater streams...43

Table 3.2: The metrics to be candidates for inclusion in the final metrics the southeastern coastalplain (Ecoregion75) blackwater reference streams 43

Table 3.3: Southern coastal plain (Ecoregion 75) blackwater (BW) stream index. Imp = impaired. Ref = reference...44

Table 3.4: Metrics and the corresponding discrimination efficiency of southern coastal plain (Ecoregion 75) clearwater streams 46

Table 3.5: Pearson product correlation for southern coastal plain (Ecoregion 75) clearwater streams..46

Table 3.6: The metrics that were candidates to form the final index for the southeastern coastalplain(Ecoregion75) clearwater streams....................................47

Table 3.7: Southern coastal plain ecoregion (75) clearwater (CW) stream Macroinvertebrate Index values. Imp=impaired and Ref=reference..........47

Table 3.8: Metrics that formed the best (final) Index value –southern coastal plain ecoregion (75) clearwater reference streams......................................48

Table 3.9: Metrics and corresponding discrimination efficiency of southeastern plain streams (Ecoregion 65)...50

Table 4:0: Correlations of the metrics of Southeastern Plain (Ecoregion 65) streams...51

Table 4.1: The candidate metrics for inclusion in the macroinvertebrate index for all streams in the southeastern plain (Ecoregion 65)................................51

Table 4.2: Southeastern plain (Ecoregion 65) macroinvertebrate index values for all streams. CW = clearwater, BW = blackwater, Imp = Impaired, and Ref = reference..........52 -53

Table 4.3: Metrics that formed the final macroinvertebrate index value – Southeastern plain (Ecoregion 65) - all reference streams..........54

Table 4.4: Macroinvertebrate metrics and corresponding discrimination efficiencies for southeastern plains (Ecoregion 65) blackwater streams..........55

Table 4.5: Correlations of the metrics of the southeastern plain black water streams..........56

Table 4.6: The metrics that are candidates for inclusion in the final macroinvertebrate index for the southeastern plain (Ecoregion 65) blackwater streams..........65

Table 4.7: Southeastern plain ecoregion blackwater (BW) streams macroinvertebrate index value. Imp = impaired, Ref= reference..........66

Table 4.8: Metrics that formed the final macroinvertebrate index - southeastern plains (Ecoregion 65) blackwater reference streams..........66

Table 4.9: Metrics with discrimination efficiency of 50% or greater in southeastern plain (Ecoregion 65) clearwater streams..........68

Table 5: Pearson product correlation coefficient of southeastern plain (Ecoregion 65) clearwater streams..........68

Table 5.1: The candidate metrics inclusion in the final macroinvertebrate index for southeastern plain (Ecoregion 65) clearwater reference streams..........69

Table 5.2: Macroinvertebrate index value for southeastern plain (Ecoregion 65) clearwater (CW) streams. Imp=impaired, Ref= reference..........69

Table 5.3: Definitions of narrative assessments using index values-Southerncoastal plain reference streams..........76

Table 5.4: Definitions of narrative assessments using index values- Southerncoastal plain clearwater reference streams..........76

Table 5.5: Definitions of narrative assessments using index values- Southerncoastal plain blackwater reference streams..........78

Table 5.6: Definitions of narrative assessments using index values southeastern plain clearwater reference streams..........81

Table 5.7: Definitions of narrative assessments using index values southeastern plain reference streams...81

Table 5.8: Definitions of narrative assessments using index values southeastern plain blackwater reference streams...84

ACKNOWLEDGEMENTS

Funding for this project was provided through a grant from the Georgia Department of Natural Resources Division (GAEPD), under the auspices of the United States Environmental Protection Agency (specifically, United States Environmental Protection Agency Clean Water Act, Section 319(h) FY 98 - Element 1) funding. I thank for their guidance and assistance during the course of the field and laboratory work.

I am appreciative of the help provided by Duncan Hughes who trained me in multimetric analysis. Mrs. Rita Snell provided valuable office management and friendly help. I thank the graduate student John Olson for helping me during the field visits (in the South east), through which I gained first hand experience in habitat assessment and enjoyed the natural beauty of Georgia. Marcie Parrish, Tracy Ferring, Uttam Rai, Michelle Brosset for helping me in the lab, Jennifer Lang who helped in identifying the chironomids, Jodi Williams and George Williams for their assistance to both field and laboratory work. My wholehearted gratitude goes to Mrs. Susan Nichols for her comforting words and the delicious treats that she provided. I thank Dr.George Stanton and Dr.Hanley and the faculty staff for their wonderful support during the course of field and lab work. Finally I thank Dr.Gore for his precious advice, which made me achieve my goal at Columbus State University. My sincere thanks to my husband Mr.Pradeep Pillai for providing support. My two sons Master.Nithin Pillai and Master.Naveen Pillai who supported me all along to fulfill my dream.

INTRODUCTION

The rapid bioassessment approach to water resource monitoring is largely a North American phenomenon; however, it does combine some elements of the European saprobien system (Kolkwitz and Marson 1908). The saprobien system (Kolkwitz and Marson 1908) is an empirical approach that assesses stream sites by the tolerance of their invertebrate assemblage to organic pollution. Rapid assessment approaches differ from the saprobien system and traditional statistically based studies in that they are usually characterized by involving more than one type of measurement. These measurements are summarized for comparison to predetermined thresholds rather than relying on statistical comparisons of the individual measures and are referred to as multimetric approaches (Resh *et al.* 1995). The multimetric approach involves defining an array of measures, or metrics, that individually provide information on diverse biological attributes and, when integrated, provide an overall indication of the condition of the biological community (Barbour *et al.* 1995).

Rapid procedures for assessing water quality, using biotic communities of rivers and streams, have become widely accepted in recent years as they allow a large number of sites to be examined at relatively low cost (Resh and Jackson 1993).Rapid bioassessment procedures (Plafkin *et al.* 1989) have been widely distributed and tested across the United States. Biological assessment for streams has advanced considerably in the past decade, and now includes methods using fish (Karr *et al.*1986, Ohio EPA 1987, Lyons 1992) and benthic macroinvertebrates (Plafkin *et al.*1989, Kerans *et al.*1992, Kerans and Karr 1994). Several organismic assemblages are used to assess the condition

of biological communities; however, benthic macroinvertebrates are the most widely used (Hellawell 1986, Rosenberg and Resh 1993, Southerland and Stribling 1995).

Biological assessment is the evaluation of the biological condition of a water body using biosurvey and other direct measurements of resident biota in surface waters. Resident biota are natural monitors of environmental quality and can reveal the effects of episodic as well as cumulative pollution and habitat alteration (Plafkin *et al.*1989, Barbour *et al.*1995). A biosurvey of invertebrates and other benthic features can provide important insights into changes in stream water quality (Rosenberg and Resh 1993). A biosurvey is the process of collecting and processing representative portions of a resident aquatic community to determine the community structure and function.

Biocriteria are numeric values or narratives that describe biological preferences for physical and or chemical conditions based upon designated reference sites. Biocriteria contribute directly to water resource management programs and to water quality standards regulation, by measuring the condition of the water resource at a site through surveys and assessments of resident biota. Biocriteria are a critical tool for natural resource agencies in protecting the quality of water resources.

All biological monitoring programs share an origin in the Clean Water Act §303 (d), in which the maintenance of the biological integrity of all surface waters are mandated (Resh *et al.*1995). State water quality standards provide the criteria from which impacted waters are identified and evaluated for non-point sources of pollution (as required by §319 [Clean Water Act (CWA)]); for example, Total Minimum Daily Loads (TMDLs) also regulated under §303(d) [CWA]). Biological criteria are stipulated by the

United States Environmental Pollution Act to be implemented into State water quality standards. Bioassessment is ideally suited to identify aquatic life use impairments and evaluate the relative magnitude of impairment. From this evaluation, the identification of pollutants leads to a determination of TMDLs, further to mitigate pollutant loadings and restore the water body to meet designated uses (Barbour *et al.* 1995).

Stream ecosystems have generally been viewed as systems which process allochthonous inputs, particularly leaf litter and other large organic debris (Fisher and Likens 1973, Fisher 1977) upon which stream organisms are dependent (Minshall 1967, Cummins *et al.* 1973). This concept has been modified to consider the biological strategies and dynamics of river systems and requires consideration of a gradient of physical factors formed by the drainage network; often referred to as the River Continuum Concept (RCC) (Vannote *et al.* 1980).

Lateral linkages with the riparian zone are as vital as the longitudinal linkages emphasized in the RCC (e.g., Cummins *et al.* 1984). Litter may reach streams by direct fall or lateral movement (Benfield 1997). Litter fall may be defined as allochthonous material entering streams from riparian vegetation. In temperate deciduous forests, the bulk of litterfall occurs in autumn but material may continue entering streams by lateral movement over the remainder of the year (Benfield 1997). Studies performed on fourth- to sixth-order blackwater river streams showed that the ratio of primary productivity to respiratory demand, P/R, remains less than one (Edwards and Meyer 1990). This is contrary to the RCC prediction for the same order of streams where P/R ratio is predicted to be greater than one (Vannote *et al.* 1980). The P/R remains less than one, in the fourth- to sixth-order blackwater streams because of high rate of respiration, which

appears to be fueled by allochthonous inputs of organic matter from the extensive riparian swamps (Edwards and Meyer 1987b, Cuffney 1988); an aspect not originally considered by the RCC (Vannote *et al.*1980, Minshall *et al.*1983). Although the importance of direct litter fall from bank side trees will decrease as rivers grow wider, floodplain inputs can increase (Meyer 1990).

Streams and rivers of Georgia flow through a mosaic of watershed conditions in seven ecoregions and many subecoregions including agricultural, commercial, swamps, forests and residential areas. In some ecoregions, there are two apparently different types of streams: blackwater streams and clearwater streams.

Blackwater streams are found in a diversity of biomes throughout the world from boreal coniferous forests (Naiman 1982) to tropical rainforests (Sioli 1975). These rivers may arise from white-sand soils (Spodosols or Entosols) in Amazonia (Anderson 1981), although similar rivers elsewhere arise from peat or swamp soils (Klinge 1967). The white sands are usually eroded from ancient aeolian or alluvial sandstones (Hardon 1936, Janzen 1974) and probably are the most nutrient poor soils in the world (Arens 1963, Hardon 1937, Heyligers 1963, Janzen 1974).

Blackwater streams are a common feature in the southeastern coastal plains of the United States. They are low gradient streams accompanied by a broad and productive flood plain forest that is generally inundated several months each year (Benke and Meyer 1988). These regions generally have sandy soils, with a low capacity to absorb dissolved organic carbon leached from terrestrial vegetation (St. John and Anderson 1982) and washed into the river, staining their waters brown (Meyer 1986). Blackwater streams are

characterized by low pH, a tea color, low conductivity, shifting sand substrate, low primary productivity (Edwards 1985) and are poor in crtical ions (St. John and Anderson 1982). The benthic substratum throughout the coastal plain is much finer than described by the traditional River Continuum Concept streams (Bott *et al.*1985) and consists primarily of medium to coarse sand (Gillespie *et al.* 1985) with varying degrees of deposited organic matter.

Sand is often thought to be rather unsuitable substrate for macroinvertebrates due to its instability (Hynes 1970).The shifting substratum is unsuitable for many invertebrate species and they are confined to more stable woody debris (Cudney and Wallace 1980, Benke *et al.*1984, Wallace and Benke 1984). However, these sandy blackwater streams have a low content of suspended sediments but a high concentration of dissolved organic matter (DOM) (Benke 1990). Potential sources of DOM are diverse. Contributions from rainfall, soil run-off, tree canopy leachates, sediments, groundwater, algal excretions and leaching of biological detritus all add DOM to streams (Larson 1978).

Generally, in most river systems, inorganic constituents (approximately 120mg/l) are much more abundant than dissolved organic carbon (about 10mg/l) (Beck *et al.* 1974). However, the main constituents of blackwater organic matter are humic substances (Lamar 1968). Organic components, principally the humic and fulvic acid solubles and aggregated particulates, appear to be very resistant to biological degradation and are known to have carbon content half-lives on the order of 600 years (Schnitzer 1971). Following rainfall, large volumes of dark brown organic rich waters can be seen flushing from the swamps into streams. Lignin is the main precursor of humic materials (Flaig *et al.* 1975), but other phenolics (especially tannin) might also be important

contributors (St. John and Anderson 1982). These humic materials have been described as acidic, dark colored, partially aromatic, and chemically complex substances with molecular weights ranging from a few hundred to several thousand kg/mol (Schnitzer1971). The humic materials contain: 1) fulvic acids, 2) humic acids and 3) humins, based on their solubility (Schnitzer 1971).The humic substances possess a high ion exchange capacity, due to the presence of a large number of carboxyl and phenolic hydroxyl groups (Beck *et al.* 1973). The abundance of such acidic material would obviously lower the pH of river water and also affect the distribution of carbon species. Water high in tea color contains a large proportion of readily oxidizable carbon compounds and also less organic nitrogen relative to those of low color (Gjessing 1976).

Dissolved Organic Carbon (DOC) which is high in humic compounds (Beck *et al.* 1974; Gjessing 1976), has been assumed to be refractory, *i.e.* resistant to bacterial metabolism (Edwards and Meyer1987). Meyer *et al* (1987) have shown that a portion of the DOC found in blackwater streams will support bacterial growth as labile DOC (Meyer *et al.* 1987), given the large concentrations in these rivers. Riverine DOC is chemically similar to soil fulvic acid (Meyer 1986, Beck *et al.* 1974, Leenher 1980). A study using the modification of wet combustion method of Slater (1954), from samples taken from the white clay creek (Pennsylvania, U.S.A.) demonstrated that the total DOC is one-half the approximate concentration (in mg/L) of dissolved organic compounds (Larson 1978). Another study done on two low-gradient blackwater rivers in Georgia, the sixth-order Ogeechee river and the fourth-order Black creek, molecular weight distribution of DOC in these rivers has been estimated, they are DOC> 10,000nMW, DOC 1000-10,000nMW and DOC<1000nMW respectively (Meyer 1986). In this

particular study, in the sixth- order Ogeechee river, it was estimated that 25% of the DOC is high MW, 61% is intermediate MW, and 17% is low molecular weight fractions (Meyer 1986).Carbohydrates and phenolics accounted for about 20% of total DOC in the sample (Meyer 1986). Bacteria may be important in transforming this carbon into particulate form, thereby making it available to higher trophic levels either through direct ingestion by bacterial biomass or indirectly through the protozoan pathway (Pomery1979; Porter *et al.* 1980). In a sixth-order blackwater river, Carlough and Meyer (1990) estimated that grazing by protozoa was sufficient to clear almost half the water column of suspended bacterial cells each day.

Studies performed on the Ogeechee River basin, a blackwater river in Georgia, showed that input of organic matter from floodplains has consequences for ecosystem processes along the river continuum (Meyer1990, Meyer1986, Meyer *et al.* 1987). The turnover length of organic carbon in the blackwater river was longer because so much of the organic carbon was present as refractory DOM, which was easily transported downstream. For a moderate size southeastern blackwater river, this transport distance was reported to be 680km (Edwards and Meyer 1987a).

Studies have shown that the number of bacteria in the water column of blackwater streams was higher than those found in most freshwater and marine environments (annual average 1.5×10^{10}cells/l) (Edwards 1987) and that the guts of many invertebrates were filled with amorphous detritus rather than the remains of algae, vascular plant detritus, or animals (Wallace *et al.* 1986). Bacterial numbers increase as the river waters rise, and were found to be greatest during the first flood of the season (Meyer 1990) .This demonstrates the importance of floodplain and riparian swamps as

an important source of bacteria, as well as other organic matter in the rivers (Meyer 1990).

Janzen (1974) suggested that blackwater streams are unproductive. On the contrary, Benke *et al.* (1984) determined that macroinvertebrate production in the Satilla River, a large blackwater river in Georgia, was at least as high as that reported for comparable clearwater streams. Benke *et al.* (1984) also found that the highest diversity of taxa was on snags rather than in the sandy and muddy substrates in the Satilla River. The major food source for these snag invertebrates originated from the swamp in the form of suspended soil bacteria or fine particulate organic matter (FPOM) (Edwards 1987, Edwards and Meyer 1987a, Wallace *et al.*1987). Morse *et al.* (1984) found 89% of all organisms collected in Upper Three Run Creek, South Carolina to occur on snags. Nilson and Larimore (1973) noted that this production is primarily due to intensive colonization by filter feeding organisms that find snags the only suitable substrate in the river.

Snags are important to the retention of allochthonous coarse particulate organic matter (CPOM), which would otherwise be flushed downstream (Smock *et al.* 1985). Coarse Particulate Organic Matter (CPOM) has been defined as the particulate organic matter greater than 1mm in diameter (Bird and Kaushik 1981). CPOM may be of allochthonous origin, e.g., leaves, wood, bark, flowers, bud scales, insect frass, etc introduced to the stream, or of autochthonous origin, e.g. macrophyte and filamentous algae (Bird and Kaushik 1981) indigenous to the stream. The snags and their accumulated leaf litter should be of paramount importance to production in these low order streams, given the importance of leaf material as a substrate and food source for

macroinvertebrates (Cummins and Klug 1978, Smock *et al.* 1985). Snag habitat shrinks and expands, as fluctuating water levels cause either habitat desiccation or inundation (Jacobi and Benke 1991).

The quantity, quality, timing, and retention of allochthonous inputs (CPOM) to streams are a function of watershed characteristics (Hynes 1975, Meehan *et al.*1977). Spring and early summer inputs, although quantitatively smaller, consist primarily of high-nutrient pollen, flower parts, and insect frass (Fittkau 1964, Sedell *et al.* 1974). On the contrary leaves entering the streams in autumn are nutrient poor because trees absorb most of the soluble nutrients that were present in the leaves (Paul *et al* 1978,Subercrop *et al.* 1976). Allochthonous input from the coniferous forest and evergreen deciduous forests is of great significance to the winter- active forms as they show a more even distribution of inputs throughout the year and form two third of the productivity of the stream (Hynes 1961). The coniferous forest and evergreen deciduous forests streams show a more even distribution of inputs throughout the year.

Concomitant changes in macroinvertebrate community composition and production between upstream and downstream areas of the stream can be expected to occur due to the influence of swamp systems (Smock *et al.* 1985). In the coastal plain regions, where water temperatures may exceed 20° C for six months of the year, larval insect development often becomes less synchronous and the adult emergence period is more extended (Bishop 1973). A high fraction of mayfly species found on the Ogeechee river snags were multivoltine (Baetidae, Heptageniidae, Caenidae, Tricorythidae, Oligonueriidae) attributed to a high mean annual temperature (Jacobi and Benke 1991).

Simulidae (black flies) are a productive component of the invertebrate fauna in streams like the Ogeechee (e.g.; Benke *et al.* 1984) and can effectively capture bacterial carbon and incorporate it into body tissue (Edwards and Meyer 1987a). Mayflies such as *Stenonema* are abundant on woody debris in the Ogeechee River and feed on flocculent organic matter that collects on these surfaces (Meyer 1990). The other productive components of invertebrate fauna in the Ogeechee and other blackwater rivers include collector–gatherers such as chironomids and oligochaets, as well as filtering collectors such as bivalves and chironomids (Benke *et al.* 1984, Smock *et al.* 1985, Stites 1986) as direct consumers of bacteria (Meyer 1990). Filter feeders attached to woody debris are the most productive component of blackwater invertebrate fauna (Smock *et al.* 1985). Scrapers are rare in blackwater rivers (Benke *et al.* 1984, Smock *et al.* 1985, Smock and Roeding 1986), collector-gatherers like chironomids and the mayfly feed on the material attached to snags (Meyer 1990).

Clearwater streams are considered to be the complement of blackwater streams, where the pH and conductivity are higher than blackwater streams, and substrates are more variable with a combination of gravel, cobble, and boulders with a greater frequency pool and, riffle sequences.

In a clearwater watershed, the binding of humic material to clay particle is responsible for the difference in water color. Clay is well known to adsorb a variety of organic substances (Greenland 1965a) and act as a filter that prevents the passage of humic materials through oxisol and other clear-water producing soils.

The Georgia Environmental Protection Division (GAEPD) has begun a multi-phased project to develop biological criteria for wadeable streams and rivers in the state, to be based on a scientifically defensible set of standards. The initial step for biological criteria development required the assessment of baseline (or reference) biological and chemical conditions in each of the ecoregions of the state. Ecoregions have been proposed as the basic geographic units for establishing reference conditions (NRC 1992), because water chemistry and stream biology are known to differ among many ecoregions (Hughes 1995, Omernik 1995). Ecoregions are characterized by apparent homogeneity in geographic characteristics that are likely to be associated with spatial patterns in habitat, nutrients, food, and impairment (Omernik 1987). Ecoregion delineation provides a useful geographical framework that subdivides large sections of Georgia into logical units of similar geology, soils, land use/land cover, and water quality. Establishing these ecological regions is important because the structure and function of many aquatic biological communities vary from one geographic area to another. Characteristic reference conditions must be established for each ecoregion by assessing the structure and function of reasonably unimpacted streams in that region. A comparison of the characteristic reference metrics can be used to establish the degree of impairment.

As a component of the larger Georgia EPD sponsored project to characterize reference conditions in the major ecoregions of Georgia, this study is focused upon determining if there is a need to create two reference conditions in some ecoregions, *i.e.*, in the ecoregions where blackwater and clearwater streams co-occur. Additionally, within the constraints of Rapid Bioassessment Procedure (the procedure used by the State of Georgia), and using only those criteria, should there be a blackwater stream condition

distinct from the more common clearwater condition? Since blackwater streams occur primarily in the Southeastern plain and Southern coastal plain ecoregions of Georgia, the major focus of this project will be in differences in the two stream types within these two ecoregions.

MATERIALS AND METHODS

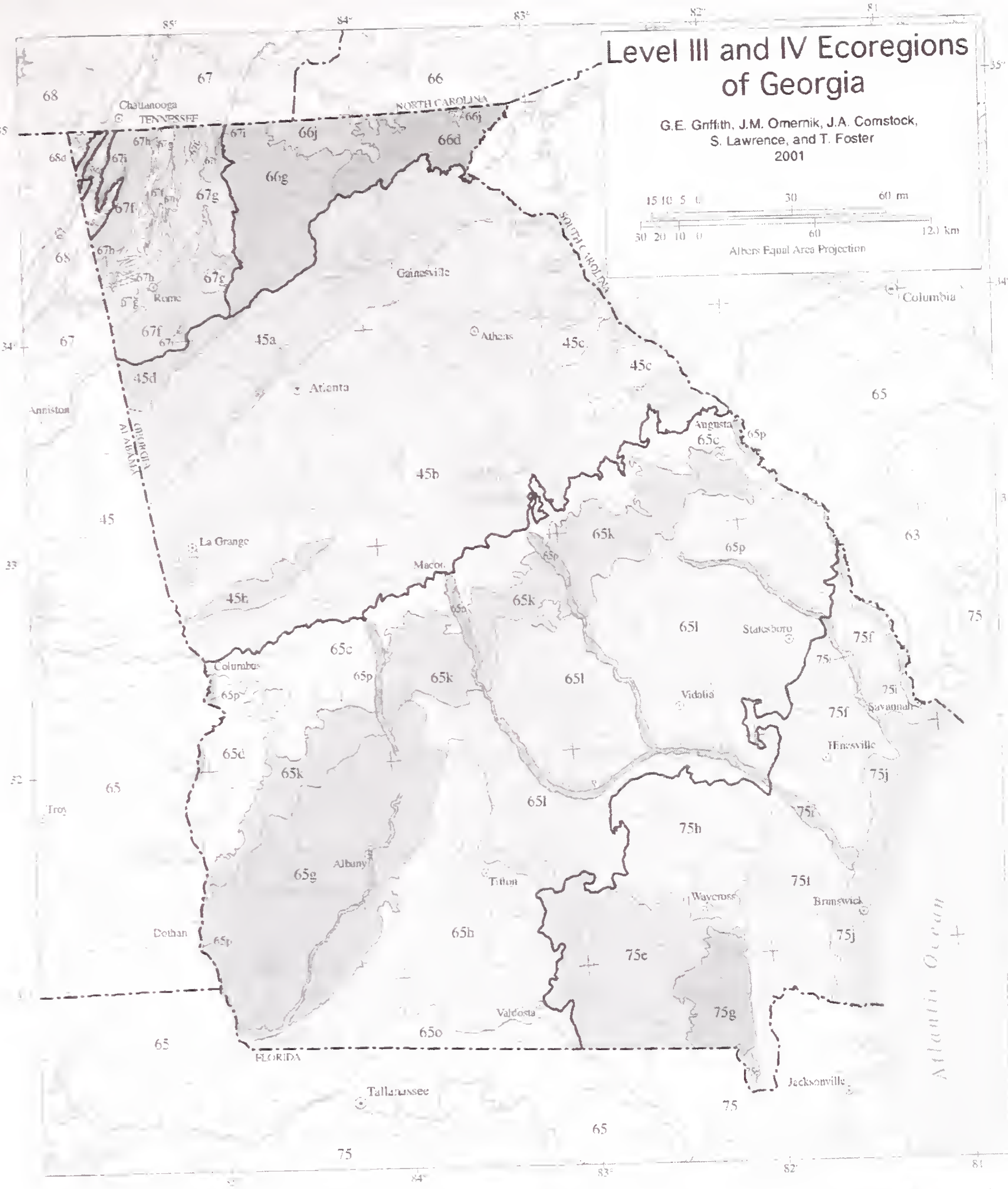
The study area for the Georgia Ecoregions Project included the state of Georgia and the area of catchments shared with the neighboring states of Tennessee, Alabama, North Carolina, and Florida; an area of 153,169 km^2 (Olson 2002). Candidate reference catchments and stream sites were selected using land use and topographic maps, physical habitat sampling, aerial photography, remote sensed land-use data (MLRC), and other digital data (Olson 2002, Gore *et al. 2004*). Initially, streams with minimum impairments in ten categories related to nonpoint source contaminated were selected by GIS analysis as potential candidate reference streams. Physical habitat and visual assessments were used to select at least five candidate catchments in each subecoregion as characteristic minimally impaired streams. Region 4 stream reference conditions for the southeastern United States are as shown in table 1.1 (QAPP 2002).

Table 1.1 Criteria for selection of stream reference sites in the southeastern U.S (Olson 2002)

Step	Criteria	Action	Means of Evaluation
1	% Urban land use	Screen out sites with > 15%	
2	% Agriculture	Screen out sites with > 50%	GIS evaluation of MRLC data
3	Road Density	Select lowest Density	Evaluation of DOT GIS data
4	Minimum Riparian Zone	Screen out sites with < 15m width	GIS evaluation of MRLC
5	Channel Alteration	Screen out sites with any alteration	Evaluation of map/aerial photo
6	Impoundments	Select lowest Density	Evaluation of USGS lake data
7	Point Source Discharges	Screen out sites with any discharges	EPA NPDES permits
8	% Silviculture	Select lowest Density	GIS evaluation of MRLC data

Sites that met the filtering criteria (Table 1.1) and were accessible were designated as candidate reference sites for physical, chemical and biological sampling.

As previously mentioned, at least five candidate sites were chosen to represent streams that flowed through the prominent landscape features in each ecoregion or subecoregion. Ecoregion designations reflect the major differences found in topography, physiography, climate, elevation, hydrology, vegetation, wildlife, land use, and surface geology as reflected by soil across Georgia (see table 1.2) (Griffith *et al.* 2001). Each of these ecoregions is subdivided into subecoregions that reflect a higher resolution of change in these variables: that is, upon fine scale differences in climate, physiography, soils, surficial geology, vegetation, land use, and water chemistry (Gallant *et al.* 1989). The subecoregions divide the state into 28 areas, ranging in size from 290 to 31,590km^2 (Figure 1 and table 1.3).



45 Piedmont
- 45a Southern Inner Piedmont
- 45b Southern Outer Piedmont
- 45c Carolina Slate Belt
- 45d Talladega Upland
- 45h Pine Mountain Ridges

- Level III ecoregion
- Level IV ecoregion
- State boundary
- County boundary

65 Southeastern Plains
- 65c Sand Hills
- 65d Southern Hilly Gulf Coastal Plain
- 65g Dougherty Plain
- 65h Tifton Upland
- 65k Coastal Plain Red Uplands
- 65l Atlantic Southern Loam Plains
- 65o Tallahassee Hills/Valdosta Limesink
- 65p Southeastern Floodplains and Low Terraces

66 Blue Ridge
- 66d Southern Crystalline Ridges & Mountains
- 66g Southern Metasedimentary Mountains
- 66j Broad Basins

67 Ridge and Valley
- 67f Southern Limestone/Dolomite Valleys and Low Rolling Hills
- 67g Southern Shale Valleys
- 67h Southern Sandstone Ridges
- 67i Southern Dissected Ridges and Knobs

68 Southwestern Appalachians
- 68c Plateau Escarpment
- 68d Southern Table Plateaus

75 Southern Coastal Plain
- 75e Okefenokee Plains
- 75f Sea Island Flatwoods
- 75g Okefenokee Swamp
- 75h Bacon Terraces
- 75i Floodplains and Low Terraces
- 75j Sea Islands/Coastal Marsh

Table 1.2. Descriptions of Georgia Ecoregions. Data for elevation and slope represent the range for ± 5 Standard deviations from the mean.

Ecoregion code	Ecoregion name	Geology	Elevation (Ft)	Slope(degrees)	Drainage pattern	Principle Land use/Vegetation)	Climate
65	South-eastern plain	Sedimentary (Cretaceous Miocene)	110-517	0-16	Dendritic	Agriculture, Pine Forest,&Silviculture	Mesic-Xeric
75	Southern Coastal Plain	Sedimentary (Pliocene-Pleistocene)	0-206	0-4.5	Dendritic	PineForest,Agriculture& Silviculture	Mari-time

Table 1.3. Alphanumeric designations for candidate reference sites in Georgia from which biological, physical habitat and field chemistry were sampled (QAPP 2002)

Ecoregion code	Ecoregion Type	Subecoregion type code	Subecoregion Type
65	South Eastern Plains	c	Sand Hills
		e	South Eastern Plains and Hills
		g	Douherty Plains
		h	Tifton Plains
		k	Coastal Plain Red Uplands
		l	Vidalia Upland
		o	Tallahasee Hills/Valdosta lime sink
75	Coastal Plain	e	Okefenokee Plains
		f	Sea Island Flatwoods
		h	Bacon Terraces
		j	Sea Island /Coastal Marsh

During the Georgia Ecoregions study, subecoregions 65p and 75i were excluded because each subecoregion had only a limited number of streams of the size of interest. Subecoregion 75g, the Okefenokee swamp, was also eliminated as it was assumed to have adequate ecosystem integrity and be protected since it is a designated national wildlife refuge.

As with candidate reference sites, the same criteria were employed to characterize a population of candidate stressed sites, which could then be measured for physical, chemical and biological measures of single or multiple impairments. (Hughes 2006, Gore *et al.* 2005) (Table 1.4).

Table 1.4 Criteria for selection of stream impaired stream sites in the southeastern U.S.

Step	Criteria	Action	Means of Evaluation
1	% Urban land use	Screen out sites with < 15%	
2	% Agriculture	Screen out sites with < 50%	GIS evaluation of MRLC data
3	Road Density	Select range of Densities	Evaluation of DOT GIS data
4	Minimum Riparian Zone	Includes sites with < 15m width	GIS evaluation of MRLC
5	Channel Alteration	Includes sites with any alteration	Evaluation of map/aerial photo
6	Impoundments	Select range of densities	Evaluation of USGS lake data
7	Point Source Discharges	Includes sites with a range of discharges	EPA NPDES permits
8	% Silviculture	Select a range of densities	GIS evaluation of MRLC data

At each one of the candidate reference and impaired sites, a standard set of measurements was recorded:

- Physical measurements - Wolman field pebble count and total habitat score (RBP, US.EPA, 1999).
- Chemical measurement - Turbidity, pH, conductivity, alkalinity, hardness, total phosphorus and metals (iron and copper).

- Benthic macroinvertebrates were collected as a composite 20-grab sample (Gore *et al.* 2004).

The single criterion used to separate blackwater from clearwater streams was acidity. For a blackwater stream, the pH was designated to be less than or equal to 6 and clearwater streams were designated as those with a pH greater than 6 (Barbour *et al.* 1999).

A one hundred meter reach representative of the basic characteristics of the stream was selected. Whenever possible, the area was at least 100m upstream from any road or bridge crossing to minimize its effect on stream velocity, depth and overall habitat quality for reference streams. In addition, there were no tributaries discharging into each study area. A map of the sampling reach was drawn, which included in-stream attributes (*e.g., riffles, falls, fallen trees, pools, bends etc.*) and important structures, plants, and attributes of the bank and near stream areas. Sampling began at the downstream reach and proceeded upstream.

A D-Frame net (U.S Standard No. 30, 600μm mesh openings) was used for sampling benthic macroinvertebrates in accordance with the Georgia EPD approach for allocation of sample effort (or jabs) among sub habitat types (Georgia DNR 1999). Sampling was conducted over three years (beginning in September, 2000, and finishing in February, 2003), using the index periods between September and February. Sampling focused on areas of stable habitat structure within the reach and included woody debris/snags (8 jabs), bottom substrate (3 jabs), undercut bank or root wad (6 jabs), and leaf packs (3 handfuls) for low gradient streams. Each benthic macro invertebrate sample, a composite of all 20"jabs", was field preserved (Benfield 1997) in 95% ethanol with

proper internal labeling and assigned a serial log number. Serial log numbers were also recorded on chain-of-custody (COC) forms and each person handling or transporting samples were noted on COC forms until delivered to the CSU environmental laboratory.

Methods of sample processing were based upon EPA's RBP (Barbour *et al.* 1999) and included use of a gridded screen for increasing subsampling efficiency as described by Caton (1991). The initial or primary sample processing included sorting, subsampling, and re-sorting checks. The sample was rinsed in a 500μm-mesh sieve to remove fine sediment. Large organic material like whole leaves twigs, algae or macrophyte mats, *etc*., were rinsed and discarded. The sorting tray consisted of two-part, rectangular pan (36 cm by 30 cm) with a rectangular sieve insert, marked with grids, measuring 36 cm^2. Macroinvertebrates were selected from each of these small cells, chosen at random, until 200 individuals had been collected. Any organism that was lying over a line separating two grids was considered to be on the grid containing its head. If the density of organisms was sufficiently high that there were more than 240 organisms in the first four cells, the contents were transferred to a second gridded pan. Then new cell-grids were randomly selected for a second level of sorting as was done for the first, sorting grid-cells, one at a time, until 200 organisms were found.

Benthic macroinvertebrates were identified to the lowest possible taxonomic level. The majority of the specimens were identified to genus. Specimens that were damaged or of a very early instar were identified only to family level.

Secondary macroinvertebrate processing included taxonomic identification and verification procedures, tabulation, enumeration, and calculation of metrics.

Metric Selection

Metrics are biological attributes of the benthic community that indicate existing water quality conditions. Metrics attempt to quantify aspects of the structure and function of the benthic community and may be divided into five major groups: taxonomic richness, composition, tolerance/intolerance, functional feeding group and habit.

Taxonomic richness: These metrics describe numbers of distinct taxa within taxonomic groups *(e.g. Total Taxa, EPT Taxa, and Diptera Taxa*). High taxonomic richness usually correlates with excellent water quality and health of the stream.

Composition: The composition metric indicates the proportion of individuals in a sample belonging to a specific taxonomic group. Some composition measures may also serve as tolerance/intolerance metrics (*e.g., % Chironomus* species & *Cricotopus sp. / Total Chironomidae*) where certain families or genera have an established higher tolerance to pollution than the other members of the order or family.

Tolerance/Intolerance. The tolerance metric represents the general level of tolerance to broadly-defined pollution levels in the stream. Some are weighted scores based upon tolerance classes (*e.g.*, Beck's Index) (Beck 1965), and some are based upon the average tolerance values of individual taxa within the sample (*e.g.*, the North Carolina Biotic Index) (Lenat 1993).

Functional Feeding Group. Functional feeding groups indicate dominant feeding mechanisms of the biological assemblage. Some specialized feeders are more sensitive to disturbance and pollution than more generalized feeders (Rosenberg and Resh 1996).

Habit. The habit metric includes taxa richness and composition measures describing movement and positioning mechanisms of benthic organisms (*e.g.*, swimmer taxa, % sprawlers*)* *(*Merritt and Cummins 1996).

Combining individual metrics into a multimetric index allows integration of different indicators into a single ecologically based index. Approximately seventy different biological metrics were evaluated for this study. Candidate metrics from the Ecological Data Application System Version 3.3.2k (EDAS) (TetraTech 2001) were derived for each reference site. Only metrics with an established response to stress (*e.g.*, from RBP or other literature) were used in final index development.Other factors considered for candidate metric evaluation included importance within the ecoregion or subecoregion under examination, low incremental cost, responsive to stressors on a regional scale, and feasibility of method of measurement on a regional scale (Hughes 2006). A list of candidate metrics, metric category, and responsive to stress is included in table 1.5.

Table 1.5: Definitions of best candidate benthic metrics and predicted direction of metric response to increasing perturbation (Stress Response-S.R) (compiled from DeShon 1995, Barbour *et al*. 1996, Fore *et al*. 1996, Smith and Voshell 1997).

Category	Metric		S.R
Richness measures	Total Taxa	Measures the overall variety of the macroinvertebrates assemblage	▼
	EPT Taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera	▼
	Ephemeroptera Taxa	Number of mayfly taxa (usually genus or species level)	▼
	Plecoptera Taxa	Number of stonefly taxa (usually genus of species level)	▼
	Trichoptera Taxa	Number of trichoptera taxa (usually genus or species level)	▼
	Coleoptera Taxa	Number of Coleoptera taxa (usually genus or species level)	▼
	Diptera Taxa	Number of Diptera taxa (usually genus or species level)	▼

	Chironomidae Taxa	Number of chironomidae taxa (usually genus or species level)	▼
	Tanytarsini Taxa	Number of Tanytarsini taxa (usually genus or species level)	▼
	Evenness	Measure of relative abundance	▼
	Beck BI	Biotic community at each site	▼
	CrMol Taxa	Number of taxa Cricotopus	▼
	Shannon-Wiener_base_e	Incorporates both richness and evenness in a measure of general diversity	▼
	Simpson's 'Diversity	Measure of diversity	▲
Composition measures	EPT Pct	Percent of the composite of mayfly, stonefly, and caddis fly larvae	▼
	Ephemeroptera Pct	Percent of mayfly nymphs	▼
	Amphipoda Pct	Percent of amphipods	▼
	Chironomidae Pct	Percent of Chironomidae	▲
	Coleoptera Pct	Percent of beetle larvae and aquatic adults	▼
	Diptera Pct	Percent of dipterans	▲
	Gastropoda Pct	Percent of snails	▼
	Isopoda Pct	Percent of isopods	▲
	Noninsect Pct	Percent of noninsect	▲
	Odonata Pct	Percent of Odonata	▲
	Plecoptera Pct	Percent of Plecoptera	▼
	Tanytarsini Pct	Percent of Tanytarsini	▼
	Oligochaeta Pct	Percent of Oligochaete	▲
	Trichoptera Pct	Percent of Trichoptera	▼
	%Chironominae/TC	Percent of Chironominae	▲
	%Tanypodinae/TC	Percent of Tanypodinae	▲
	Hydropsychidae/Trichoptera	Percent of hydropsychids in Trichoptera	▲
	Hydropsychidae/EPT	Percent of hydropsychids in EPT	▲
	Tanytarsini/TC	Percent of Tanytarsini	▼
	Cricotopus&Chironomus/	Percent of Cricotopus and chironomus	▲
Tolerance or Intoleranc measures	Tolerant Taxa	Taxa richness of those organisms considered to be sensitive to perturbation	▲
	Tolerant Pct	Percent of macrobenthos considered to be tolerant of various types of	▲
	Intolerant Taxa	Taxa richness of those organisms considered to be sensitive to perturbation	▼
	Intolerant Pct	Percent of macrobenthos considered to be sensitive to various types of	▼
	Dominant01 Pct	Measures the percent of dominance of the single most abundant taxon. Can	▲
	Dominant01 Individuals	Measures the dominance of the single most abundant taxon. Can be	▲
	HBI	Abundance-weighted average tolerance of assemblage of organisms	▲
	NCBI	Abundance-weighted average tolerance of assemblage of organisms	▲
Feedding ding measures	Scraper Pct	Percent of the macrobenthos that scrape or graze upon periphyton	▼
	Scraper Taxa	Taxa of the macrobenthos that scrape or graze upon periphyton	▼
	Collector Pct	Percent of collector functional feeding group	▼
	Collector Taxa	Percent of collector functional feeding group	▼
	Predator Pct	Percent of predator functional feeding group	▼
	Predator Taxa	Taxa of predator functional feeding group	▼
	Shredder Pct	Percent of shredders functional feeding group	▼
	Shredder Taxa	Taxa of shredder functional feeding group	▼
	Filter Pct	Percent of the macrobenthos that filter FPOM from either the water column	▲
	Filter Taxa	Taxa of the macrobenthos that filter FPOM from either the water column or	▼

Habit measures	Clinger Taxa	Number of insects having fixed retreats or adaptations for attachment to	▼
	Clinger Pct	Percent of insects having fixed retreats or adaptations for attachment to	▼
	Burrower Taxa	Number of burrower taxa	▼
	Climber Taxa	Number of taxa of insects	▼
	Sprawler Taxa	Number of taxa of insects	▼
	Swimmer Taxa	Number of taxa of insects	▼

Metrics were calculated using the lowest taxonomic level, usually genus. The ability of metrics to detect differences between impaired and reference sites were determined by calculating discrimination efficiency (DE) (Gore *et al.* 2005). The discrimination efficiency is a numerical description of the separation between metric value distributions of reference and impaired sites. It is calculated as a percentage of {DE = 100 by a/b}, for metrics that decrease with stress,

a = number of stressed samples scoring below the 25th percentile of reference site distribution

b = total number of stressed sites

And, for metrics that increase with stress,

a = the number of stressed sites scoring above the 75th percentile of the reference site distribution

b = total number of stressed sites.

Metrics whose discrimination efficiency was greater than 50% were selected for creating the final macroinvertebrate index. A Pearson product-moment correlation analysis was performed so that redundant metrics could be avoided in the final index. Metrics that had a high correlation ($r \geq 90$) were not used in the same index. This procedure ensured that each metric contributed independent information to the

aggregated index. A high priority was given to selecting at least one metric within each of the metric categories to further reduce redundancy.

To create the final macroinvertebrate index for each ecoregion or subecoregion, the candidate metrics were standardized on scale of 0 to 100 (Hughes *et al* 1998, Hughes 2006, Middleton 2006). The standardization was based upon the metric's response to stress. For metrics which were expected to increase with stress (higher values represent worst sites), the fifth-percentile value was assigned the best score of 100; thus, reducing the effect of outlier values. The scoring was performed using the equation:

$$\text{Score} = (X_{max} - X/X_{max} - X_5)*100$$

Where X_{max} = maximum possible value.

X_5 = 5th percentile value

For the metrics that are expected to decrease in value with increasing site impairment (*i.e.*, higher values represent better sites), the 95th percentile was assigned a score a score of 100. This scoring was done using the equation:

$$\text{Score} = (X/X_{95} - X_{min})*100$$

Where X_{min} = minimum possible value

X_{95} = 95th percentile value

Index Development

The selected metrics were scored and then averaged to create a single index value. The effectiveness of the working index was tested by analyzing its DE when comparing reference and impaired sites. The DE of the working index for classifying the data reference sites was found according to the equation below:

DE = A/B, where A = Number of reference sites scoring above the 25th percentile of the original data reference sites, B = the total number of data reference sites (Hughes *et al.* 1998, Hughes 2006, Gore *et al.* 2005, Middleton 2006).

Data Analysis

The ultimate goal of the Georgia Ecoregions Project was to characterize the reference condition and to determine which metrics most appropriately characterized that condition for comparison to potential impaired stream sites in each ecoregion. A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour *et al.*1995). Metric calculations were automated through the Ecological Data Application System (EDAS) and spreadsheet calculations provided by Tetra-Tech, Inc. (Barbour *et al.* 1999). The response of 57 metrics to stress is shown in Table 1.5. The standardized score for each site is summed to an index value for each site. The summed score for each site is converted to narrative assessments, for example: very good, good, fair, poor and very poor (Stribling *et al.*1999, Middleton 2006).

Although there are, no doubt, distinct ecological differences between clearwater and blackwater streams, both in composition and function, the objective of my study was to determine if the metrics used in RBP protocols could distinguish these differences. That is, will the bioassessment rating scores be different; and, if so, what physicochemical or biological factors contribute to these differences? In order to assess the potential differences between clearwater and blackwater streams and their ultimate role in the bioassessment process, the metrics that clearly distinguished clearwater from blackwater streams within the same ecoregion were determined. Furthermore, an index to

distinguish blackwater impaired from blackwater reference conditions and an index to distinguish clearwater impaired from clearwater reference conditions was also created using the techniques described above with the streams separated into distinctive categories.

Cluster Analysis

Cluster analysis (Bray-Curtis) (Faith *et al*. 1987) was completed to segregate physical and chemical conditions for blackwater and clearwater streams. Prior to analysis, the data were revitalized on a scale of 0 to 1. For the purposes of this research, I concentrated on both the southeastern plain (ecoregion 65) and the southern coastal plain (ecoregion 75), since these ecoregions contain large concentrations of both blackwater and clearwater streams.

Principal Components Analysis

The location of distinct community clusters in the n-dimensional space of a Principal Components analysis (Goodall 1954) was used to reveal several alternatives. If blackwater and clearwater streams clustered together in the same *ordination space*, then it could be concluded that the same metrics can be used in evaluating streams of that region. If blackwater and clearwater streams clustered differently along *the ordination space*, then it could be concluded that different physical, chemical, and biological conditions characterize the reference conditions and that a larger set of metrics will ultimately have to be measured in these regions so that an adequate estimate of ecosystem integrity could be produced. The PCA ordination of the sites was done using the PC-ORD software (McCune and Mefford 1997). The data were revitalized on a scale of 0 to

1 scale as they were expressed in different units (some in percentages, some just numerical).

RESULTS

Chemical and Physical Data Analysis of Reference Streams

The chemical data demonstrating differences between clearwater and blackwater streams of southeastern plain are shown on table 1.6. In the southeastern plain the blackwater streams have low pH values, alkalinity and hardness compared to the high values found in clearwater streams. A slight overlap in the values of alkalinity and hardness were observed. The raw *in situ* and lab data for chemical analysis are presented on Appendix A.

Table 1.6. Southeastern plain ecoregion blackwater reference and Clearwater reference streams indicating differences in pH, alkalinity and hardness.

Chemical parameter	**Black water streams N=10**			**Clearwater Streams N =19**		
	Range	Mean	Standard deviation	Range	Mean	Standard deviation
Alkalinity(mg/l as $CaCO_3$)	0.0-7.13	1.4	2.34	6.17-175.99	44.09	49.24
pH(SU)	4.1-5.88	5	0.64	6.09-7.15	6.7	0.34
Hardness(mg/l as $CaCO_3$)	4.26-22.227	14.1	14	8.38-196.99	62.4	61.2

In the southern coastal plain, blackwater streams, the pH, alkalinity and hardness, again, had lower values than comparable clearwater streams (table 1.7). There was only one reference clearwater stream identified at the time of study. The rest of the streams were tidal and those steams were not included in this study.

Table 1.7. Southern coastal plain ecoregion blackwater reference and Clearwater reference streams indicating differences in pH, alkalinity and hardness.

Chemical parameter	Blackwater streams N =7			Clearwater streams N = 1		
	Range	Mean	Standard deviation	Range	Mean	Standard deviation
Alkalinity(mg/l as $CaCO_3$)	0.0-8.56	2.2745	3.7	20.89	20.89	0
pH(SU)	3.91-5.72	4.6875	0.7	6	6	0
Hardness(mg/l as $CaCO_3$)	2.837-7.69	4.52938	5.1	40.13	40.13	0

Cluster analysis of the chemical and physical data demonstrated that clearwater and blackwater streams were observably different (fig. 2). At the 75% significance level, five distinct clusters were recognized. Two of those clusters were entirely blackwater streams. The other two clusters consisted entirely of clearwater streams. One cluster contained both blackwater and clearwater streams. The final clustering, joining 65g-62.65g-82.65k-68 and 65k-85 had very high alkalinity compared to the other streams.

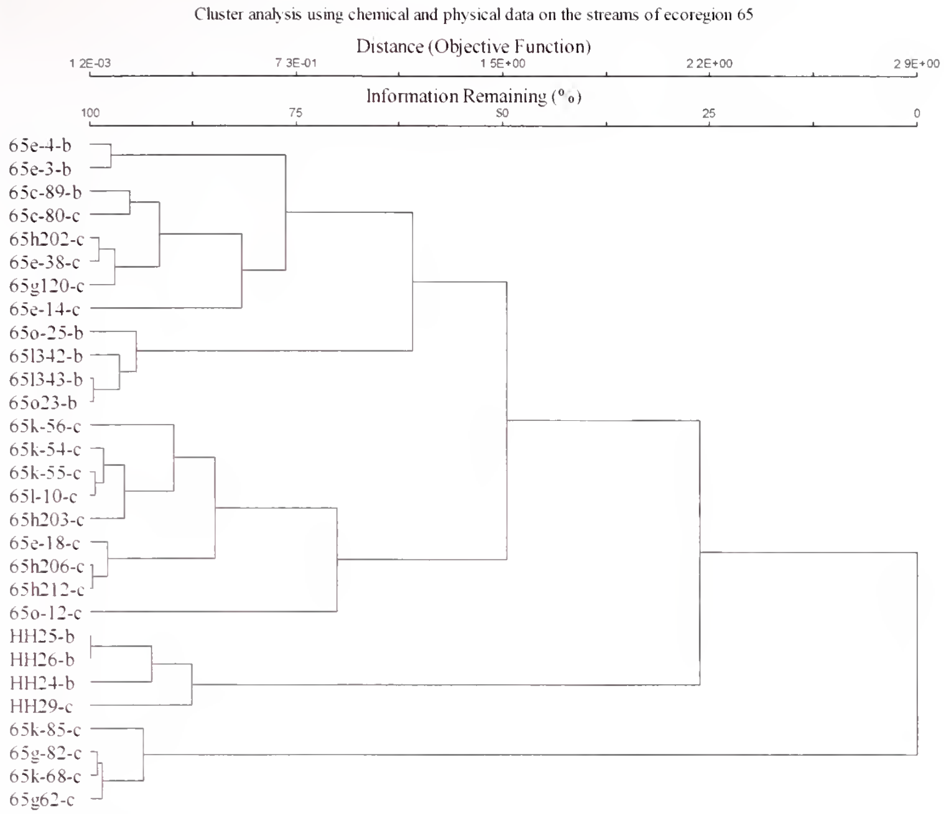


Figure 2: Dendrogram analysis of chemical and physical conditions of southeastern plain streams. Blackwater streams are designated as "-b" and clearwater streams are designated as "-c".

The cluster analysis of the chemical and physical data from the southern coastal plain streams created two distinct clusters at 73% significance (fig. 3). The blackwater streams formed one cluster and the second cluster contained blackwater streams and the only clearwater stream (75f-126). The stream sites 75f-126 and 75j-31 had high alkalinity and hardness.

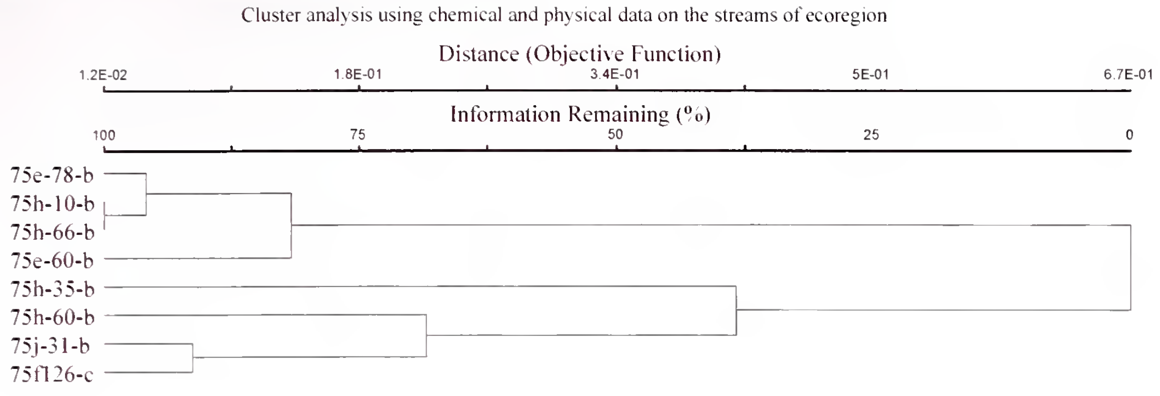


Figure 3: Dendrogram analysis of chemical and physical conditions of southern coastal plain streams. Blackwater streams are designated as "-b" and clearwater streams are designated as "-c

Habitat Score Analysis of Reference Streams

Blackwater streams in the southeastern plain had high total habitat scores ranging from 149-174 (table 1.8). Comparable clearwater streams had habitat scores ranging from 121-171.

Table 1.8: Total habitat score (visual habitat assessment) for blackwater and clearwater reference streams of southeastern plain ecoregion.

Physical character	Southeastern plain ecoregion	
	Blackwater streams N =10	**Clearwater streams N=19**
Range of Total Habitat Score	149-174	121-171
Mean	166	154
Standard deviation	7	14

Table 1.9: Total habitat score (visual habitat assessment) for blackwater and clearwater reference streams of southern coastal plain ecoregion.

Physical character	**Southern coastal plain ecoregion**	
	Blackwater streams N =8	**Clearwater streams N =1**
Range of Total Habitat	145-181	164
Mean	165	164
Standard deviation	12	0

Because of the low number of clearwater streams in the southern coastal plain ecoregion, there were no observable differences between habitat scores (table 1.9).

Substrate Analysis of Reference Streams

The Wolman pebble counts for references streams showed interesting results. The blackwater streams of the southeastern plains are dominated by sand substrate (table 2) as were clearwater streams (table 2.1).

Table 2: Wolman pebble count in selected south eastern plain blackwater streams

StationID	**County**	**Waterbody name**	**Silt/Clay**	**Sand**	**Gravel**
65c-89	Chattahoochee	Hollis Creek	0	100	0
65d-3	Chattahoochee	Hollaca Creek	4	96	0
65d-4	Chattahoochee	Sally Branch	48	52	0
65l-342	Telfair	Opposum Creek	16	84	0
65l-343	Telfair	Fishing Creek	5	95	0
65o-23	Lowndes	Clyatt Mill Creek	6	100	0
65o-25	Lowndes	trib to New River	6	94	0
HH24	Taylor	Whitewater Creek	0	89	11
HH25	Marion	Pine Knot Creek	0	100	2
		Median	6	96	6.5

Table 2.1: Wolman pebble count of selected southeastern plains clearwater streams.

StationID	County	Waterbody name	Silt/Clay	Sand	Gravel
65c-80	Webster	Lanahassee Creek	23	77	0
65d-14	Stewart	Hannahatchee Creek	20	80	0
65d-18	Stewart	Grass Creek	4	91	5
65d-38	Clay	Waukeefriskee Creek	7	92	1
65g-120	Early	Odom Creek	20	50	30
65g-62	Dougherty	Kiokee Creek	31	69	0
65g-82	Baker	Keel Creek	100	0	0
65h-202	Decatur	Callahan Branch	7	94	0
65h-203	Decatur	Fourmile Creek	30	70	0
65h-206	Gadsden	Shaw Creek	2	98	0
65h-212	Gadsden	South Mosquito Creek	2	98	0
65k-54	Wilkinson	Maiden Creek	1	99	0
65k-55	Wilkinson	Cedar Creek	7	93	0
65k-56	Wilkinson	Porter Creek	7	91	2
65k-68	Twiggs	Crooked Creek	30	67	3
65k-85	Houston	Okeetuck Creek	74	25	1
65l-10	Burke	Mill Creek	5	94	1
65o-12	Grady	Hadley Creek	43	57	0
HH29	Early	Coheelee Creek	0	67	27
		Median	14	91	3

In the southern coastal plain (ecoregion 75) blackwater streams, the highest percentage of substrate was sand (table 2.2). However, the single clearwater stream of the same ecoregion was dominated by finer silt and clay (table 2.3).

Table 2.2: Wolman pebble count of southern coastal plain blackwater streams.

StationID	County	Waterbodyname	Silt/Clay	Sand	Gravel
75e-59	Lowndes	Ray Branch	0	100	0
75e-60	Lowndes	Meetinghouse Branch	25	71	4
75e-78	Echols	trib to Alapaha River	2	98	0
75h-10	Wayne	Keene Bay Branch	13	86	1
75h-35	Coffee	trib to Hurricane Creek	6	94	
75h-60	Pierce	trib to Alapaha	11	87	2
75h-66	Pierce	Otter Creek	54	46	0
75j-31	Camden	Todd Creek	59	41	0
		Median	13	87	2

Table 2.3: Wolman pebble count of southern coastal plain clearwater streams.

Station ID	county	water body name	Silt/Clay	Sand	Gravel
75f-126	Camden	Waverly Creek	98	2	7
		Median	98	2	7

Macroinvertebrate Composition of blackwater and clearwater reference streams

In the southeastern plain ecoregion (ecoregion 65), blackwater streams were dominated by aquatic insects such as *Polypedilum tritum* ,*Thienemannimyia group, Apedilum, Simulium, Tvetenia, Phaenopsectra,* and *Pleurocera,* as well as non-insects like *Lirceus* and *Hyalella azteca*. In comparable clearwater streams the abundant taxa were a more diverse group including *Phaenopsectra, Ablabesmyia mallochi, Hydroporus (Neoporus)L,Tanytarsus,Leptophlebidae,Polypedilum aviceps,Caecidotae,Oligochaeta, Polypedilum, Physella, Crangonyx, Dicrotendipes,Conchapelopia, Dubiraphia L, Polypedilum illinoense, Tribelos jucundus, Rheotanytarsus pellucidus, Kiefferulus, Stenonema and Cambarinae.* Common abundant taxa in both the streams were the midge, *Phaenopsectra, various oligochaeta,* and the isopod, *Lirceus.*Table 2.4 summarizes the abundant taxa for both the southeastern plain blackwater and clearwater streams.

Table 2.4: Taxa that is abundant in the southeastern plain blackwater and clearwater reference streams. A= abundant, C= Common, and R = rare.

Taxa that is abundant in the streams of Southeastern plain Ecoregion (65)		
Taxa	**Blackwater streams**	**Clearwater streams**
Polypedilum tritum	A	C
Pleurocera spp.	A	-
Lirceus spp.	A	A
Thienemanniniyia group	A	C
Hyalella azteca	A	C
Simulium spp.	A	C
Strophopteryx limata	A	R
Apedilum (Paralauterborniella)	A	C
Tvetenia spp.	A	-
Phaenopsectra spp.	A	A
Ablabesmyia mallochi	C	A
Hydroporus (Neoporus) L spp.	C	A
Tanytarsus spp.	C	A
Leptophlebidae spp.	C	A
Polypedilum aviceps	C	A
Caecidotae	R	A
Oligochaeta	A	A
Polypedilum convictum	R	A
Physella spp.	-	A
Crangonyx spp.	-	A
Dicrotendipes spp.	-	A
Conchapelopia spp.	C	A
Dubiraphia L. spp.	C	A
Polypedilum illinoense	-	A
Tribelos jucundus	-	A
Rheotanytarsus pellucidus	-	A
Kiefferulus spp.	-	A
Stenonema spp.	C	A
Cambarinae	C	A

In the southern coastal plain ecoregion, blackwater streams were dominated by Polypedilum tritum, Tvetenia bavarica, Apedilum, Stenochironomus, Ablabesmyia mallochi, Nanocladius, Tribelos jucundus, Cragonyx, Polypedilum illinoense group, Simuliidae, Tribelos fusicorne, oligochaeta, Tvetenia, Phaenopsectra and non-insect taxa such as Lirceus and Hyalella azteca. The single clearwater stream was dominated by the midges, Polypedilum illinoense group and Kiefferulus; these two taxa common to both stream types. Table 2.5 summarizes taxa found in the clearwater and blackwater streams of southern coastal plain streams.

Table 2.5: Taxonomic composition of southern coastal plain blackwater and clearwater reference streams. A = abundant, C = common, and R = rare.

Taxa that are abundant in the streams Southern coastal plain Ecoregion(75) streams		
Taxa	**Blackwater streams**	**Clearwater streams**
Oligochaeta	C	C
Stenochironomus spp.	C	-
Phaenospectra spp.	C	-
Ablbesmyia mallochi	C	-
Nanocladius spp.	A	-
Tribelos jucundus	A	-
Lirceus spp.	A	-
Hydroporus(L) spp.	A	-
Leptophlebidae	A	-
Cragonyx spp.	A	C
C aecidotea	A	R
Polypedilum illinoense gp	A	A
Kiefferelus spp.	A	A
Tvetenia bavarica	A	-
Simulidae	A	-
Tvetenia spp.	A	-
Polypedilum tritum	A	-
Tribelos fusicorne	A	-

ANALYSIS

Southern coastal plain ecoregion streams (ecoregion 75)

The Southern coastal plain ecoregion (75) has clearwater streams as well as blackwater streams. The southern coastal plain extends from South Carolina and Georgia through much of central Florida and along the Gulf coast lowlands of the Florida Panhandle. Alabama. and Mississippi. From a national perspective. it appears to be mostly flat plains. but it is a heterogeneous region containing barrier islands, coastal lagoons. marshes and swampy lowlands along the gulf and Atlantic coasts. This ecoregion is lower in elevation with less relief and wetter soils than the southeastern plains. Once covered by a variety of forest communities that included trees of longleaf pine. slash pine. pond pine. beech. sweet gum. southern magnolia, white oak, and laurel oak, land cover in the region is now mostly slash pine and loblolly pine with oak-gum-cypress forest in some low lying areas, citrus groves, pasture for beef cattle and urban.

In the Southern coastal plain (ecoregion 75), of the twenty nine stream sites sampled. thirteen streams were classified as impaired sites where as sixteen were considered to be reference streams. Metrics with discrimination efficiency of 50% and above for streams in the southern coastalplain streams are listed in Appendix B. The five best performing metrics are listed in table 2.6. These metrics, percent Amphipoda, percent noninsect taxa. percent Odonata, percent Oligochaeta and percent Tanypodinae, are considered to be highly effective at discriminating reference stream sites from impaired stream sites.

Table 2.6: Metrics and their corresponding discrimination efficiency of the southern coastal plain (Ecoregion 75) streams.

	METRICS	DE
ALL STREAMS	Amphipoda Percent	54
	NonInsect Percent	54
	Odonate Percent	77
	Oligochaeta Percent	69
	PercentTanypodinae/TC	85

The Pearson product correlation for the selected metrics, percent Amphipoda, percent Noninsect, percent Odonata, percent Oligochaeta and percent Tanypodinae, showed no redundancy among the metrics (table 2.7). Thus, all of the metrics were used in index development.

Table 2.7: Pearson product correlation for southern coastal plain (Ecoregion 75) all streams.

Pearson product correlation for all streams (Ecoregion 75)					
	% Amphipoda	% Noninsect	% Odonata	% Oligochaeta	%Tanypodinae / TC
% Amphipoda	1.00				
% Noninsect	0.18	1.00			
%Odonata	-0.10	0.05	1.00		
%Oligochaeta	-0.05	0.55	-0.01	1.00	
% Tanypodinae/ TC	-0.29	0.19	0.25	0.37	1.00

These metrics that are candidates for inclusion in the final index for southern coastal plain streams all fall into the category of composition measure (table 2.8). As there were only five metrics that showed the discriminatory ability and they are not redundant to each other, all of the five compositional metrics were aggregated to form the index.

Table 2.8: The metrics that are candidates for inclusion in the final index for the southern coastal plain reference streams

	METRICS
Composition measures	Amphipoda Percent
	NonInsect Percent
	Odonata Percent
	Oligochaeta Percent
	%Tanypodinae/TC

The standardized metric scores, that were averaged to form the index, are listed in Appendix C and the final Macroinvertebrate Index values presented in table 2.9. The index was calculated as the average of the metric scores. The streams are sorted based on the performance of the index. There is a slight overlap between the impaired and the candidatereferencestreams.

Table 2.9: Southern coastal plain streams (Ecoregion 75) – macroinvertebrate index. CW_Imp = Clearwater Impaired, BW_Imp = Blackwater Impaired, CW_Ref = Clearwater Reference, and BW_Ref = Blackwater Impaired)

Southern coastal plain (Ecoregion 75) All Stream			
Station ID	Condition	Imp & Ref	Index
75f-45	CW_Imp	Impaired	33
75f-50	CW_Imp	Impaired	36
75e-46	BW_Imp	Impaired	50
75h-66	BW_Ref	Reference	52
75e-36	BW_Imp	Impaired	55
75j-4	CW_Imp	Impaired	58
75h-70	BW_Imp	Impaired	61
75f-137	BW_Imp	Impaired	64
75j-29	BW_Ref	Reference	65
75e-54	BW_Imp	Impaired	67
75j-2	CW_Imp	Impaired	69
75f-44	CW_Imp	Impaired	71
75j-15	BW_Ref	Reference	72
75e-60	BW_Ref	Reference	74
75e-20	BW_Imp	Impaired	75

75e-23	BW_Ref	Reference	79
75h-35	BW_Ref	Reference	79
75h-10	BW_Ref	Reference	79
75e-78	BW_Ref	Reference	79
75f-91	BW_Ref	Reference	80
75h-60	BW_Ref	Reference	80
75e-69	BW_Ref	Reference	81
75e-59	BW_Ref	Reference	81
75f-126	CW_Ref	Reference	82
75h-45	BW_Ref	Reference	83
75j-10	BW_Ref	Reference	83
75j-13	CW_Imp	Impaired	84
75h-1	BW_Imp	Impaired	84
75j-25	BW_Ref	Reference	87

The index was tested for the ability to discriminate between minimally impaired and stressed sites using box and whisker plots (Figure 4) and the discrimination efficiency of the index values were 75. Outliers and extremes signify variability or misclassification of stream conditions.

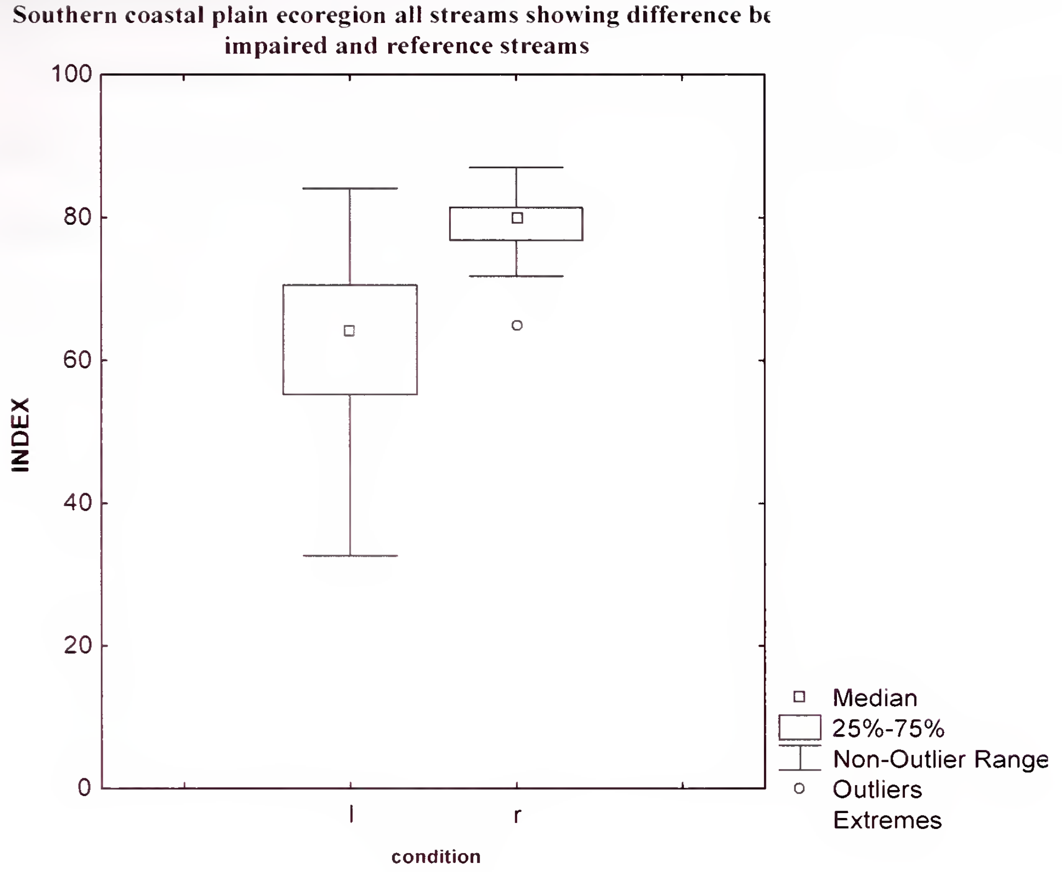


Figure 4: Index discriminating reference and impaired sites (Southern Coastal Plains – Ecoregion 75)

The 25th percentile of reference streams had a score of 78. Eighty-five percent of the impaired streams fell below the reference streams' score. There is an outlier and an anomalous stream site; not surprising considering the variability within the ecoregion.

Southern Coastal Plains (ecoregion 75) blackwater streams

Metrics for the Southern Coastal Plains blackwater streams, both impaired and reference were calculated from EDAS data. Metrics, standardized scores and the corresponding discrimination efficiency of 50% or greater are listed in appendix D. Five of the metrics that discriminated between the fifteen reference blackwater streams and the seven impaired blackwater streams were: percent noninsect taxa (71%), percent Tanypodinae (71%), percent isopoda (57%), percent odonata (57%) and percent oligochaeta (57%). Metrics that had discrimination efficiency of 50% or greater are shown below in table 3.

Table 3: Metrics and their corresponding discrimination efficiency of the southern coastal plain (ecoregion 75) blackwater streams

	METRICS	DE
Blackwater streams	Isopoda Percent	57
	NonInsect Percent	71
	Odonata Percent	71
	Oligochaeta Percent	57
	%Tanypodinae/TC	71

There appeared to be no redundancy among the blackwater stream metrics for the southern coastal plain (table 3.1).

Table 3.1: Pearson product correlation for southern coastal plain ecoregion (Ecoregion 75) blackwater streams

Pearson product correlation for southern coastal plain blackwater streams					
	Isopoda Percent	NonInsect Percent	Odonata Percent	Oligochacta Percent	Percent
Isopoda Percent	1.00				
NonInsect Percent	0.50	1.00			
Odonate Percent	0.05	-0.04	1.00		
Oligochaeta Percent	0.16	0.39	-0.07	1.00	
Percent	0.14	0.23	0.66	0.04	1.00

Metrics belonging to the compositional measure for the southeastern coastal plain blackwater streams are shown in table 3.2. Only metrics from the composition category had the ability to discriminate between reference and impaired streams.

Table 3.2: The metrics to be candidates for inclusion in the final metrics the southeastern coastal plain (Ecoregion 75) blackwater reference streams.

Metric category	Metric
Composition measure	Isopoda Percent
	Noninsect Percent
	Odonata Percent
	Oligochaeta Percent
	PercentTanypodinae/TC

Although it is recommended that metrics from all categories be included in response metrics. the only metrics that showed discriminatory ability for blackwater streams in southern coastal plain belonged to the composition measure and were not redundant to each other (table 3.2) and these metrics were aggregated to form the index values. The standardized metric scores. along with the corresponding index values. are listed in appendix E.

Table3.3: Southern coastal plain (Ecoregion 75) blackwater (BW) stream index. Imp = impaired, Ref = reference.

Southern coastal plain (Ecoregion 75) Blackwater Stream			
Station ID	**Condition**	**Imp & Ref**	**Index**
75e-36	BW_Imp	Impaired	43
75e-46	BW_Imp	Impaired	53
75f-137	BW_Imp	Impaired	55
75h-60	BW_Ref	Reference	62
75h-70	BW_Imp	Impaired	66
75e-54	BW_Imp	Impaired	72
75j-25	BW_Ref	Reference	75
75h-1	BW_Imp	Impaired	78
75h-45	BW_Ref	Reference	80
75j-10	BW_Ref	Reference	80
75j-15	BW_Ref	Reference	81
75e-59	BW_Ref	Reference	83
75e-20	BW_Imp	Impaired	83
75j-29	BW_Ref	Reference	88
75e-69	BW_Ref	Reference	92
75f-91	BW_Ref	Reference	92
75h-66	BW_Ref	Reference	95
75e-23	BW_Ref	Reference	96
75e-60	BW_Ref	Reference	97
75h-10	BW_Ref	Reference	98
75e-78	BW_Ref	Reference	100
75h-35	BW_Ref	Reference	100

Overall discriminating efficiency for the index values is 73 and the box and whisker plots illustrate the discrimination efficiency for impaired blackwater streams and reference blackwater streams (Figure 5).

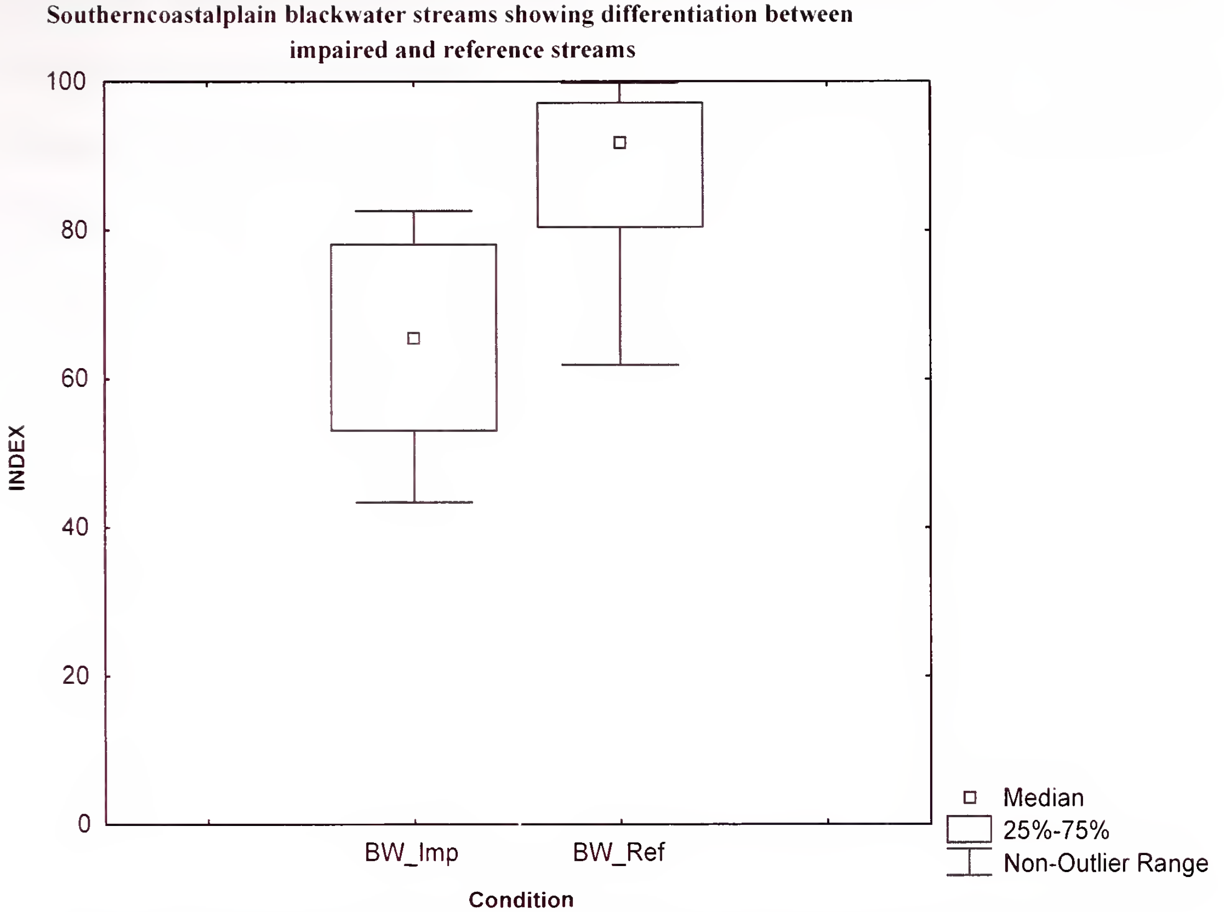


Figure 5: Index discriminating reference streams and impaired blackwater streams

(Southern Coastal Plains – Ecoregion 75)

The blackwater reference stream sites at the 25th percentile had a score of 81. Eighty-six 86% of the impaired sites scored below the 25th percentile of the reference stream sites.

Southern Coastal Plain (ecoregion 75) Clearwater streams

Discrimination efficiency between the single southern coastal plain clearwater reference streams and southern coastal plain clearwater impaired streams is listed in appendix F. Metrics and the corresponding discrimination efficiency of 50% or greater are presented in table 3.4. The highest discrimination efficiency (100%) was displayed by the percent Tanypodinae /Total Chironomidae metric, followed by percent Amphipoda

with a discrimination efficiency of 83.3%, predator taxa with 66.6%, while percent noninsect taxa, percent Cricotopus & Chironomus/Total Chironomidae, NCBI (North Carolina Biotic Index), and Number of Collector Taxa all shared a discrimination efficiency of 50%.

Table 3.4: Metrics and the corresponding discrimination efficiency of southern coastal plain (Ecoregion 75) clearwater streams.

	METRICS	DE
Clearwater streams.	Amphipoda Percent	83
	NonInsect Percent	50
	Percent Tanypodinae/Total chironomidae	100
	Cricotopus & Chironomus/Total chironomidae	50
	North Carolina Biotic Index	50
	Collector Taxa	50
	Predator Tax	67

Unfortunately, there were data from only one reference stream at the time of my analysis. There was showed no redundancy among the metrics (Table 3.5).

Table 3.5: Pearson product correlation for southern coastal plain (Ecoregion 75) clearwater streams

Pearson product correlation for (Ecoregion 75) clear water streams							
	Amphipoda %	NonInsect %	%Tanypodinae/Total chironomidae	Cricotopus& Chironomus/ Total Chironomidae	NCBI	Collector Taxa	Predator Taxa
Amphipoda %	1.00						
NonInsect %	-0.31	1.00					
% Tanypodinae/Total chironomidae	-0.58	0.17	1.00				
Cricotopus& Chironomus/Total Chironomidae	-0.47	0.18	-0.02	1.00			
North Carolina Biotic Index	-0.34	-0.52	0.31	-0.20	1.00		
Collector Taxa	0.23	-0.60	-0.53	0.10	-0.14	1.00	
Predator Taxa	0.27	-0.18	-0.46	0.04	-0.12	0.44	1.00

Metrics that were candidates for inclusion in the final index belonged to the composition, tolerance/intolerance and functional feeding group categories (Table 3.6).

Table 3.6: The metrics that were candidates to form the final index for the southeastern coastal plain (Ecoregion 75) clearwater streams.

Metric category	Metrics
Composition measure	Amphipoda percent
	Noninsect percent
	Percent TanypodinaeTC
	Cricotopus & Chironomus/Total
Tolerant/intolerant	North Carolina Biotic Index
Functionalfeeding group	Collector taxa
	Predator Taxa

The final index value for southern coastal plain clearwater streams are presented on table (3.7) and the standardized metric scores are listed in appendix G.

Table 3.7: Southern coastal plain ecoregion (75) clearwater (CW) stream Macroinvertebrate Index values. Imp = impaired and Ref = reference.

Southern coastal plain Ecoregion Clearwater Streams			
StationID	**Condition**	**Imp & Ref**	**Index**
75f-45	CW_Imp	Impaired	27
75j-4	CW_Imp	Impaired	51
75f-50	CW_Imp	Impaired	52
75j-2	CW_Imp	Impaired	62
75f-44	CW_Imp	Impaired	72
75j-13	CW_Imp	Impaired	88
75f-126	CW_Ref	Reference	100

The aggregate metrics that best discriminated between impaired and reference clearwater streams are presented in Table 3.8.

Table 3.8: Metrics that formed the best (final) Index value –southern coastal plain ecoregion (75) clearwater reference streams

Metrics that formed the best (final) Index value–southern coastal plain (Ecoregion 75) clearwater streams
Percent Noninsect Taxa
Total Cricotopus & Chironomus/Total Chironomidae
%Tanypodinae/Total Chironomidae
Predator taxa
Percent Amphipoda
Collector Taxa

The box and whisker plots displaying the discrimination between impaired and reference sites appears in Figure 6; the discrimination efficiency being zero.

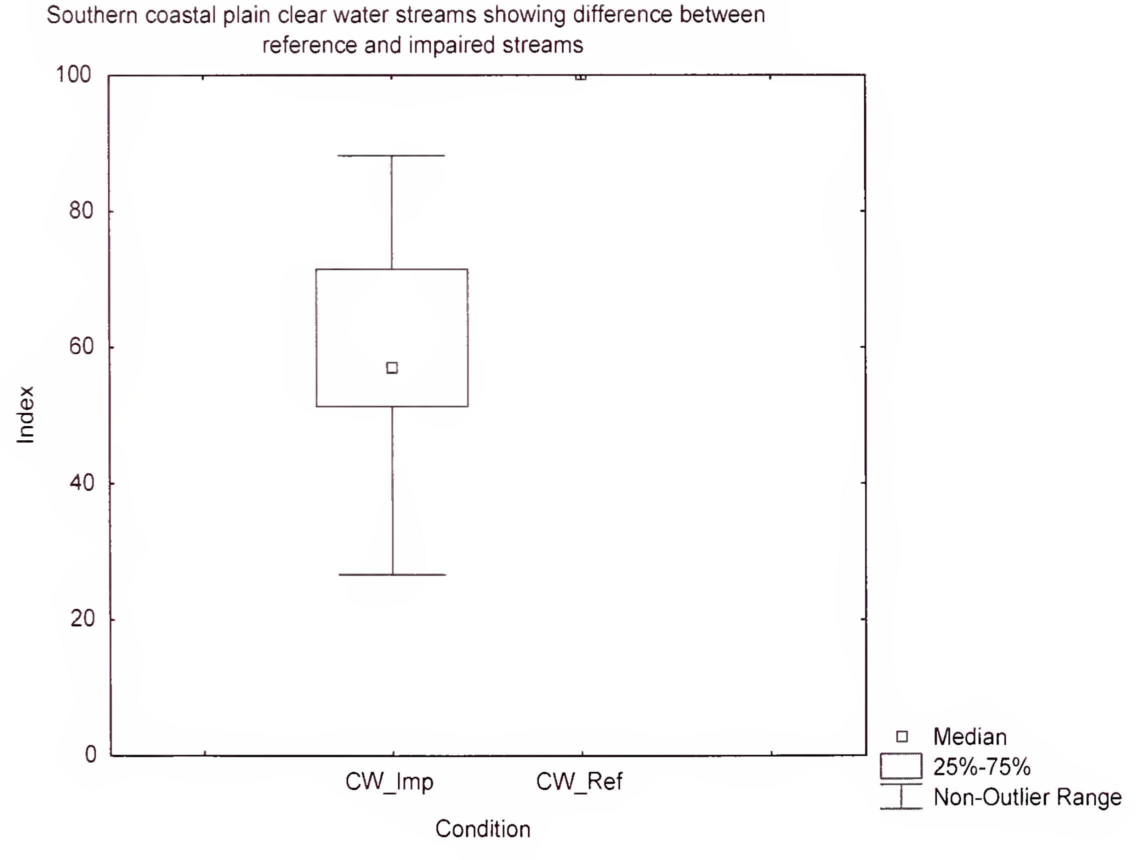


Figure 6: Index discriminating reference streams and impaired clearwater streams for the Southern Coastal Plains (Ecoregion 75)

The 25th percentile scored at 100 for the clearwater reference streams of the southeastern coastal plains. All impaired streams scored below the 25th percentile of clearwater streams. The median score represents the only clearwater reference stream of the southeastern plains.

The PCA ordination of the blackwater and clearwater streams of southern coastal plain revealed that both the stream types were scattered in the ordination space (Figure 7) with a slight cluster towards the top right side of the ordination space. The reference metrics selected to perform PCA ordination are listed in Appendix H.

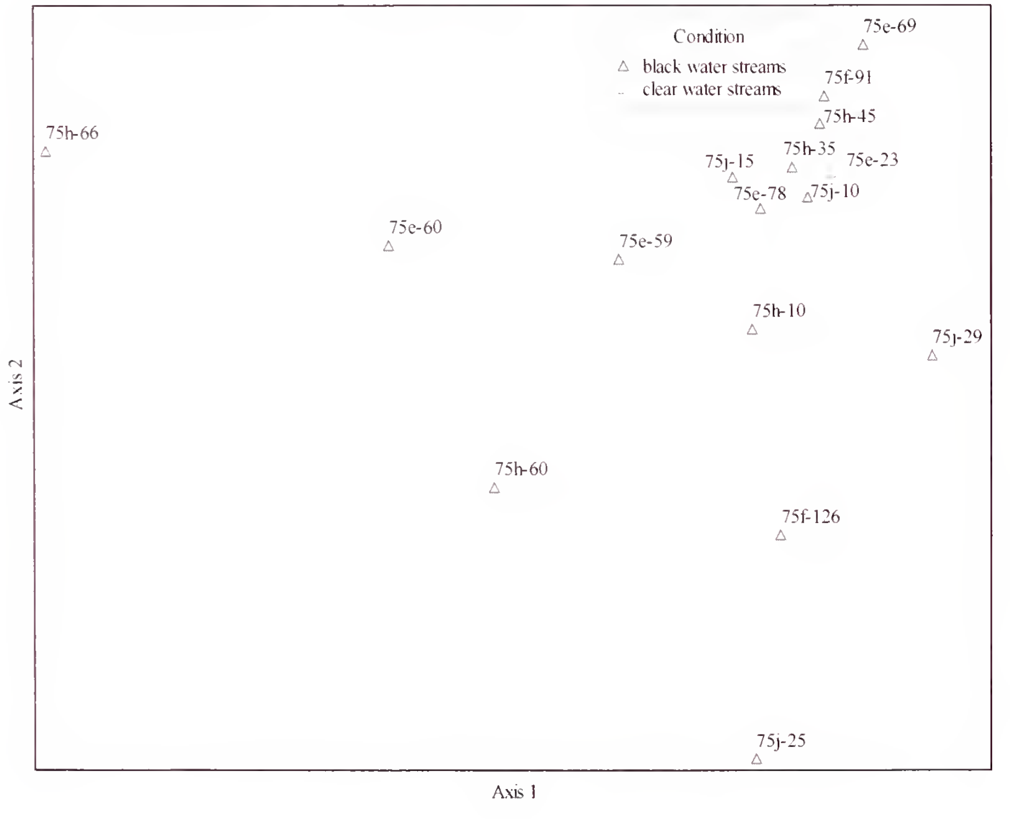


Figure 7: Principal Components Analysis of benthic metrics for the Southern Coastal Plains (Ecoregion 75) reference streams.

The 25th percentile scored at 100 for the clearwater reference streams of the southeastern coastal plains. All impaired streams scored below the 25th percentile of clearwater streams. The median score represents the most characteristic reference streams of the southeastern plains.

The PCA ordination of the blackwater streams [illegible] coastal plain revealed that both [illegible] types were [illegible] with a slight [illegible] the [illegible] metrics selected [illegible]

Figure 7: Principal Components Analysis of benthic metrics for the Southern Coastal Plains (Ecoregion 75) reference streams

The Southeastern Plains streams (Ecoregion 65)

The Southeastern plains have varied environments, as the range of physiographical and geological conditions suggest. The coastal plain has been covered by successive inundations of the sea. These irregular plains with broad instream areas have a mosaic of cropland, pasture, woodland, and forest. Natural vegetation is mostly oak-hickory-pine and southern mixed forest. Elevations and relief are greater than in the Southern Coastal Plain (Ecoregion 75), but generally less than in much of the piedmont. Streams in this area are relatively low-gradient and sandy-bottomed. There are eight subecoregions in this great plain. Vegetation on the nearby banks includes Ogeechee lime, water oak, red maple, bald cypress, titi, holly etc.

Among the 71 southeastern plain streams, metrics that discriminated the 31 reference stream sites from 40 impaired streams, and having a discrimination efficiency of 50% or greater are listed in appendix I. Those metrics and their corresponding discrimination efficiencies are presented in table 3.9.

Table 3.9: Metrics and corresponding discrimination efficiency of southeastern plain streams (Ecoregion 65).

STREAMS	METRICS	DE
All Streams	Ephemeroptera Taxa	55
	Ephemeroptera Percent	55
	Coleoptera Percent	65
	Oligochaeta Percent	74
	Tolerant Percent	52
	Predator Percent	55
	Predator Taxa	52
	Clinger Taxa	58
	Clinger Percent	55
	Tanytarsini 2chironomidae percent	77

Pearson correlation showed no redundancy among the metrics that had a discrimination efficiency of 50% and above.

Table 4: Correlations of the metrics of Southeastern Plain (Ecoregion 65) streams.

Pearson product correlation of southeastern plain streams										
	EphemTaxa	Ephem%	Coleo%	Oligo%	Toler%	Pred%	PredTax	ClngrTax	Clngr%	Tnyt2Chi%
EphemTax	1.00									
EphemPct	0.57	1.00								
ColeoPct	0.19	-0.07	1.00							
OligoPct	-0.41	-0.28	-0.29	1.00						
TolerPct	-0.28	-0.18	0.00	0.10	1.00					
PredPct	0.31	0.03	0.23	-0.36	-0.14	1.00				
PredTax	0.39	0.17	0.17	-0.44	-0.11	0.78	1.00			
ClngrTax	0.53	0.24	0.16	-0.48	-0.37	0.41	0.59	1.00		
ClngrPct	0.27	0.17	0.09	-0.16	-0.41	0.11	0.14	0.59	1.00	
Tnyt2Chi%	0.36	0.25	0.22	-0.25	-0.11	0.04	0.28	0.24	0.02	1.00

The metrics that were candidates for inclusion in the final index for southeastern plain streams belonged to the richness, composition, tolerance/intolerance values, functional feeding group, and habit measure (summarized in table 4.1).

Table 4.1: The candidate metrics for inclusion in the macroinvertebrate index for all streams in the southeastern plain (Ecoregion 65).

Metric category	Metric
Richness measure	Ephemeroptera Taxa
Composition measure	Percent Ephemeroptera
	Tanytarsini 2chironomidae percent
	Coleoptera percent
	Oligochaeta percent
Tolerance/intolerance	Tolerant percent
Functional feeding group	Predator percent
	PredatorTax
Habit measure	Clinger Taxa
	Clinger percent

The final indices of the southeastern plain streams are presented in table 4.2.

Table 4.2: Southeastern plain (Ecoregion 65) macroinvertebrate index values for all streams. CW = clearwater, BW = blackwater, Imp = Impaired, and Ref = reference.

Southeastern plain Ecoregion All Stream			
Station ID	Condition	Imp& Ref	Index
65g-84	CW_Imp	Impaired	18
65h-32	CW_Imp	Impaired	21
65l-423	BW_Imp	Impaired	26
65g-82	BW_Ref	Reference	26
65l-391	CW_Imp	Impaired	28
65g-8	CW_Imp	Impaired	29
65k-85	CW_Ref	Reference	30
65g-137	CW_Imp	Impaired	30
65h-34	CW_Imp	Impaired	30
65g-4	CW_Imp	Impaired	30
65l-379	BW_Ref	Reference	31
65g-10	CW_Imp	Impaired	31
65k-68	CW_Ref	Reference	33
65d-1	CW_Imp	Impaired	33
65g-14	CW_Imp	Impaired	34
65g-130	CW_Imp	Impaired	34
65g-135	CW_Imp	Impaired	37
65h-17	CW_Imp	Impaired	38
65k-129	CW_Imp	Impaired	40
65c-4	CW_Imp	Impaired	40
65o-11	CW_Imp	Impaired	42
65l-342	BW_Ref	Reference	43
65h-41	CW_Imp	Impaired	43
65o-18	CW_Imp	Impaired	43
65k-113	CW_Imp	Impaired	44
65L-184	CW_Imp	Impaired	44
65k-54	CW_Ref	Reference	45
65o-22	BW_Imp	Impaired	45
65l-343	BW_Ref	Reference	46
65h-209	BW_Ref	Reference	46
65l-420	BW_Imp	Impaired	47
65k-37	CW_Imp	Impaired	49
65d-4	CW_Ref	Reference	50
65g-62	CW_Ref	Reference	50
65g-69	CW_Imp	Impaired	52
65d-20	CW_Imp	Impaired	52
65d-3	CW_Ref	Reference	54
65o-25	BW_Ref	Reference	54
65c-5	CW_Imp	Impaired	57

65g-17	CW_Imp	Impaired	57
65o-12	CW_Ref	Reference	58
65c-3	CW_Imp	Impaired	60
65c-80	CW_Ref	Reference	60
65l-381	CW_Ref	Reference	60
65h-203	CW_Ref	Reference	60
65d-21	CW_Imp	Impaired	61
65l-10	BW_Ref	Reference	61
65k-56	CW_Ref	Reference	61
65d-32	CW_Imp	Impaired	62
65k-128	CW_Imp	Impaired	62
65o-24	BW_Ref	Reference	62
65c-89	BW_Ref	Reference	64
HH26	BW_Ref	Reference	65
65o-23	BW_Ref	Reference	65
65h-174	CW_Imp	Impaired	65
65c-8	CW_Imp	Impaired	66
HH25	BW_Ref	Reference	66
65c-88	CW_Imp	Impaired	66
65h-206	BW_Ref	Reference	67
65h-202	BW_Ref	Reference	68
HH24	BW_Ref	Reference	69
HH29	CW_Ref	Reference	70
65k-102	CW_Imp	Impaired	72
65d-18	CW_Ref	Reference	73
65g-83	BW_Ref	Reference	73
65d-39	CW_Imp	Impaired	74
65d-14	CW_Ref	Reference	75
65c-12	CW_Imp	Impaired	77
65c-40	BW_Imp	Impaired	79
65k-55	CW_Ref	Reference	86

The best metrics to discriminate (DE = 74) impaired and reference streams based on index values are presented in table 4.2 and the standardized metric scores are listed in appendix J.

Table 4.3: Metrics that formed the final macroinvertebratre index value – Southeastern plain (Ecoregion 65) - all reference streams.

Metrics that formed the final macroinvertebrate indices Southeastern plain streams (Ecoregion 65)
Percent Coleoptera
Ephemeroptera Taxa
Percent ClingerTaxa
Predator Taxa
Percent TolerantTaxa
Percent Oligochaeta

The box and whisker plots discriminating impaired sites from reference sites are presented in Figure 8.

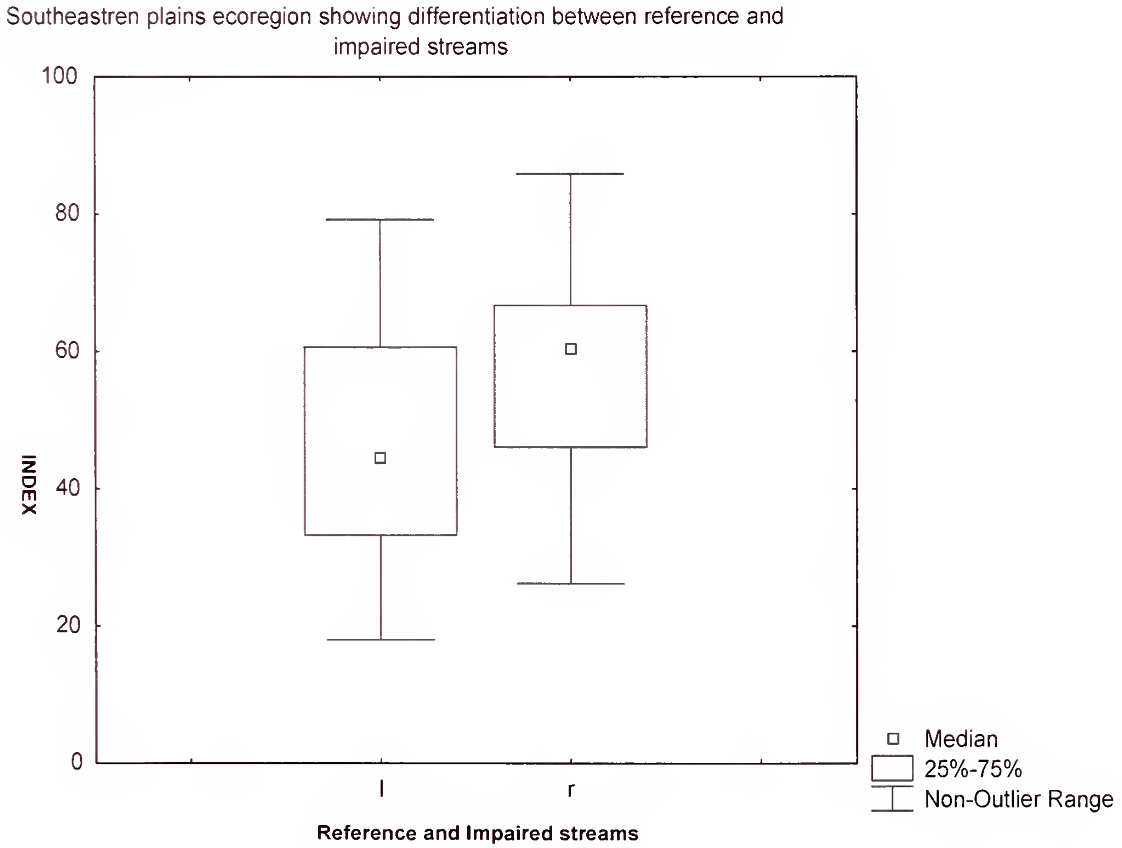


Figure 8: Macroinvertebrate Index discriminating all reference and impaired streams in the Southern Plains (Ecoregion 65).

The upper boundary of the macroinvertebrate index (the 25th percentile) for reference streams of the southeastern plain ecoregion scored at 48. Fifty-nine percent of impaired stream sites scored below the 25th percentile of the reference stream sites. The median of southeastern plains reference streams is slightly higher than the 75th percentile of impaired streams.

The Southeastern Plains (65 ecoregion) blackwater streams

Of the 20 southeastern plain blackwater streams, metrics that discriminated the 16 reference stream sites from four impaired streams and having a discrimination efficiency of 50% or greater and above are listed in appendix K. The candidate metrics and their corresponding discrimination efficiencies are presented in table 4.4.

Table 4.4: Macroinvertebrate metrics and corresponding discrimination efficiencies for southeastern plains (Ecoregion 65) blackwater streams.

Streams	Metrics	DE
Blackwater streams	Ephemeroptera Plecoptera and TrichopteraTaxa	75
	TrichopteraTaxa	75
	Evenness	50
	PredatorTaxa	50
	ClingerTaxa	50
	Diptera Percent	50
	Cricotopus & Chironomus/Total Chironomidae	50
	Tolerant Percent	50
	Percent contribution of dominant taxon	50
	Oligochaeta Percent	50
	Tolerant Taxa	75
	Dominants in common(one abundant individual taxa)	75
	Predator Percent	50
	Trichoptera Percent	75
	Ephemeroptera Plecoptera and Trichoptera Percent	75
	Ephemeroptera Percent	75

There was redundancy among some of the metrics (Table 4.5). Scattter plots were performed among the redundant metrics to determine any linear relationship between the metrics (figures 9-15).

Table 4.5: Correlations of the metrics of the southeastern plain black water streams

ECOREGION 65 BLACKWATER STREAMS CORRELATION											
	EPTTax	TrichTax	Evenness	PredTax	FiltrTax	ClngrTax	DipPct	CrCh2ChiPct	TolerPct	Dom01Pct	OligoPct
EPTTax	1.00										
TrichTax	0.92	1.00									
Evenness	0.51	0.49	1.00								
PredTax	0.78	0.70	0.70	1.00							
FiltrTax	0.76	0.67	0.57	0.62	1.00						
ClngrTax	0.94	0.89	0.61	0.82	0.77	1.00					
DipPct	0.19	0.18	0.42	0.45	0.22	0.26	1.00				
CrCh2ChiPct	-0.16	-0.08	0.21	-0.09	0.25	-0.16	-0.01	1.00			
TolerPct	-0.46	-0.48	-0.45	-0.41	-0.44	-0.54	-0.40	0.02	1.00		
Dom01Pct	-0.20	-0.20	-0.87	-0.35	-0.26	-0.31	-0.27	-0.12	0.34	1.00	
OligoPct	-0.46	-0.46	-0.23	-0.33	-0.27	-0.41	-0.12	-0.05	0.54	0.10	1.00
TolerTax	-0.36	-0.28	-0.10	-0.30	0.01	-0.39	-0.16	0.50	0.54	0.14	0.33
Dom01Ind	-0.19	-0.18	-0.85	-0.32	-0.24	-0.30	-0.29	-0.12	0.39	0.99	0.12
PredPct	0.62	0.55	0.54	0.85	0.36	0.65	0.26	-0.14	-0.41	-0.31	-0.31
FiltrPct	0.02	-0.03	0.01	-0.11	0.34	-0.02	0.39	0.10	-0.32	-0.08	0.11
TrichPct	0.69	0.79	0.42	0.45	0.58	0.72	0.09	-0.01	-0.32	-0.31	-0.32
ColeoPct	0.04	-0.02	0.31	0.10	0.11	0.07	-0.34	0.34	-0.18	-0.34	-0.14
EPTPct	0.69	0.63	0.32	0.28	0.53	0.64	0.09	-0.19	-0.44	-0.25	-0.47
EphemPct	0.18	-0.01	0.01	-0.06	0.17	0.06	0.03	-0.19	-0.28	-0.02	-0.32

Table 4.5 :Correlations of the metrics of the southeastern plain black water streams

(Continued)

ECOREGION 65 BLACKWATER STREAMS CORRELATION table 4.5 (cont..)								
	TolerTax	Dom01Ind	PredPct	FiltrPct	TrichPct	ColeoPct	EPTPct	hemPct
EPTTax								
TrichTax								
Evenness								
PredTax								
FiltrTax								
ClngrTax								
DipPct								
CrCh2ChiPct								
TolerPct								
Dom01Pct								
OligoPct								
TolerTax	1.00							
Dom01Ind	0.17	1.00						
PredPct	-0.49	-0.31	1 00					
FiltrPct	-0.04	-0.11	-0.21	1.00				
TrichPct	-0.22	-0.30	0.34	0.19	1 00			
ColeoPct	-0.08	-0.33	0.29	-0.14	0.01	1.00		
EPTPct	-0.42	-0.30	0.19	0.29	0 68	-0.04	1.00	
EphemPct	-0.32	-0.10	-0.09	0.32	-0.07	-0.07	0.63	1.00

Those metrics with correlations greater than .90 and less than -. 90 were not used in the formation of the final index. Those metrics with correlation greater than .80 and less than -.80 were not used in the formation of that same index, but were used in a different index if there was no linear relationship in the scatter plot and when there were not sufficient metrics for index generation.

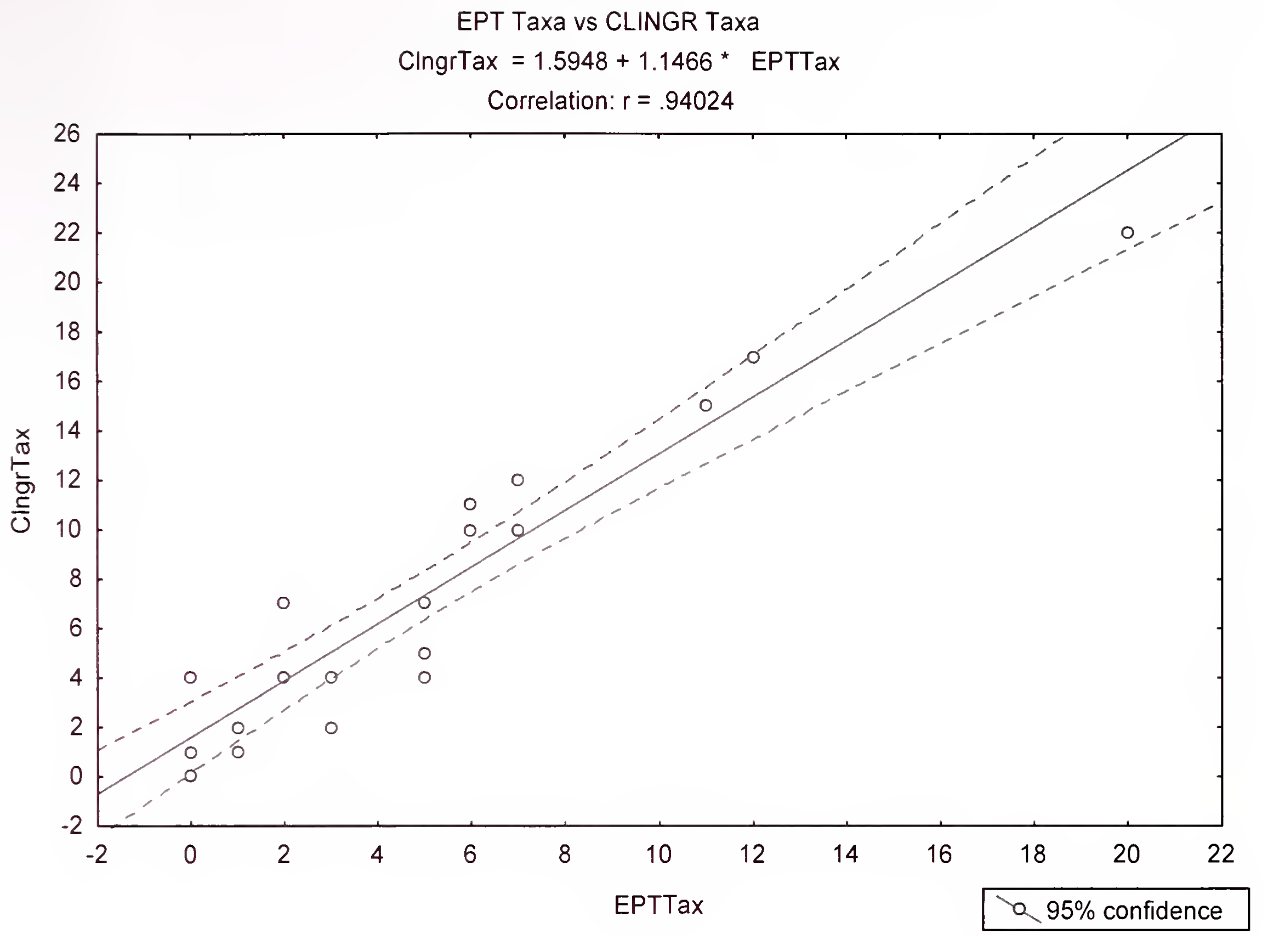


Figure 9: Scatter plot showing the relationship between EPT Taxa and Clinger Taxa in southern plains blackwater streams (Ecoregion 65)

There was a strong positive correlation (0.94) between the EPT Taxa and the clinger Taxa (figure 9). The two metrics are redundant; therefore their value as independent measures cannot be supported.

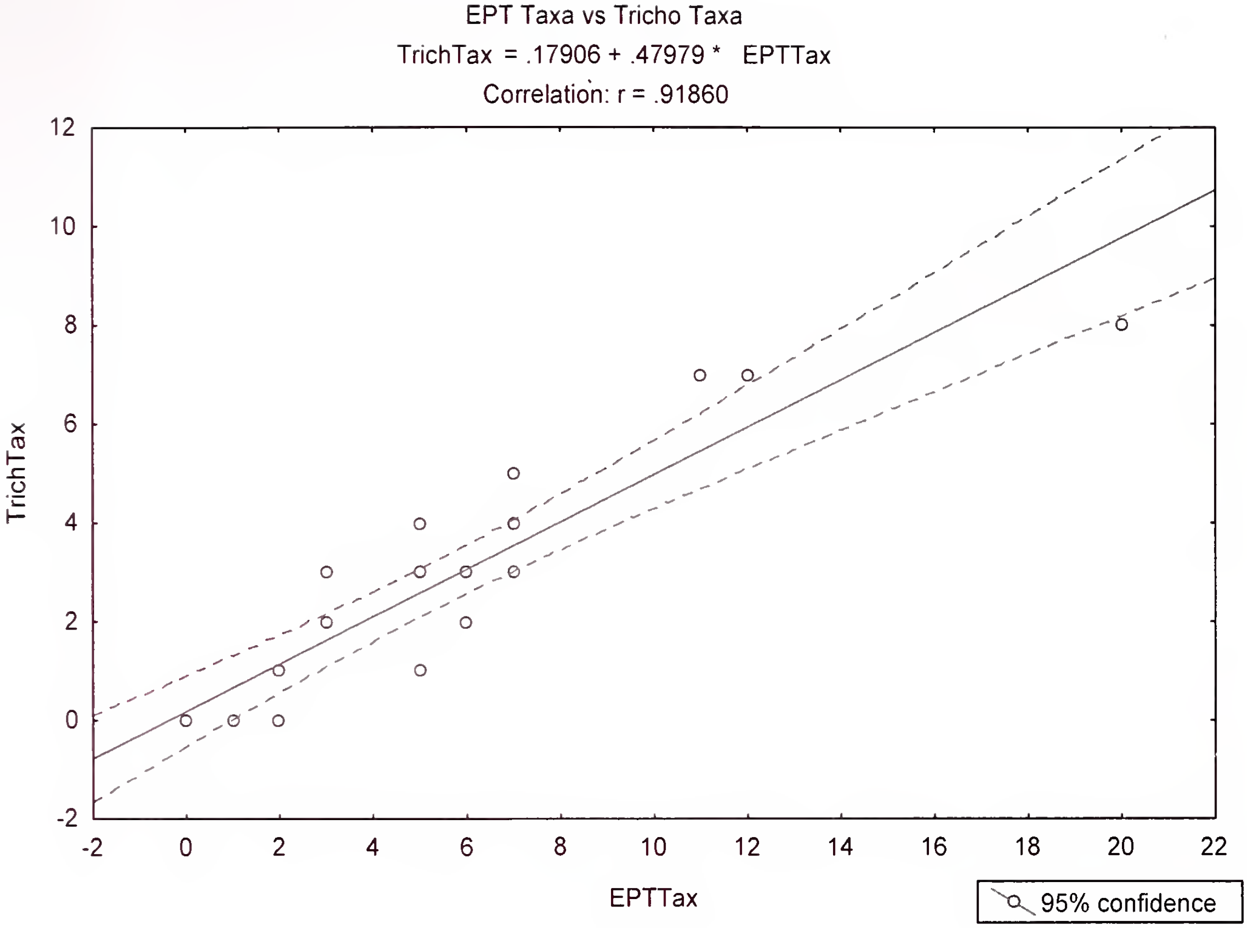


Figure 10: Scatter plot showing the relationship between EPT Taxa and Trichoptera Taxa from blackwater reference streams in the southern plains (Ecoregion 65).

There was a strong positive correlation (.91) between the EPT Taxa and the Trichoptera Taxa; the two metrics being redundant and probably contributing similar information. Their value as independent measures was unsupported.

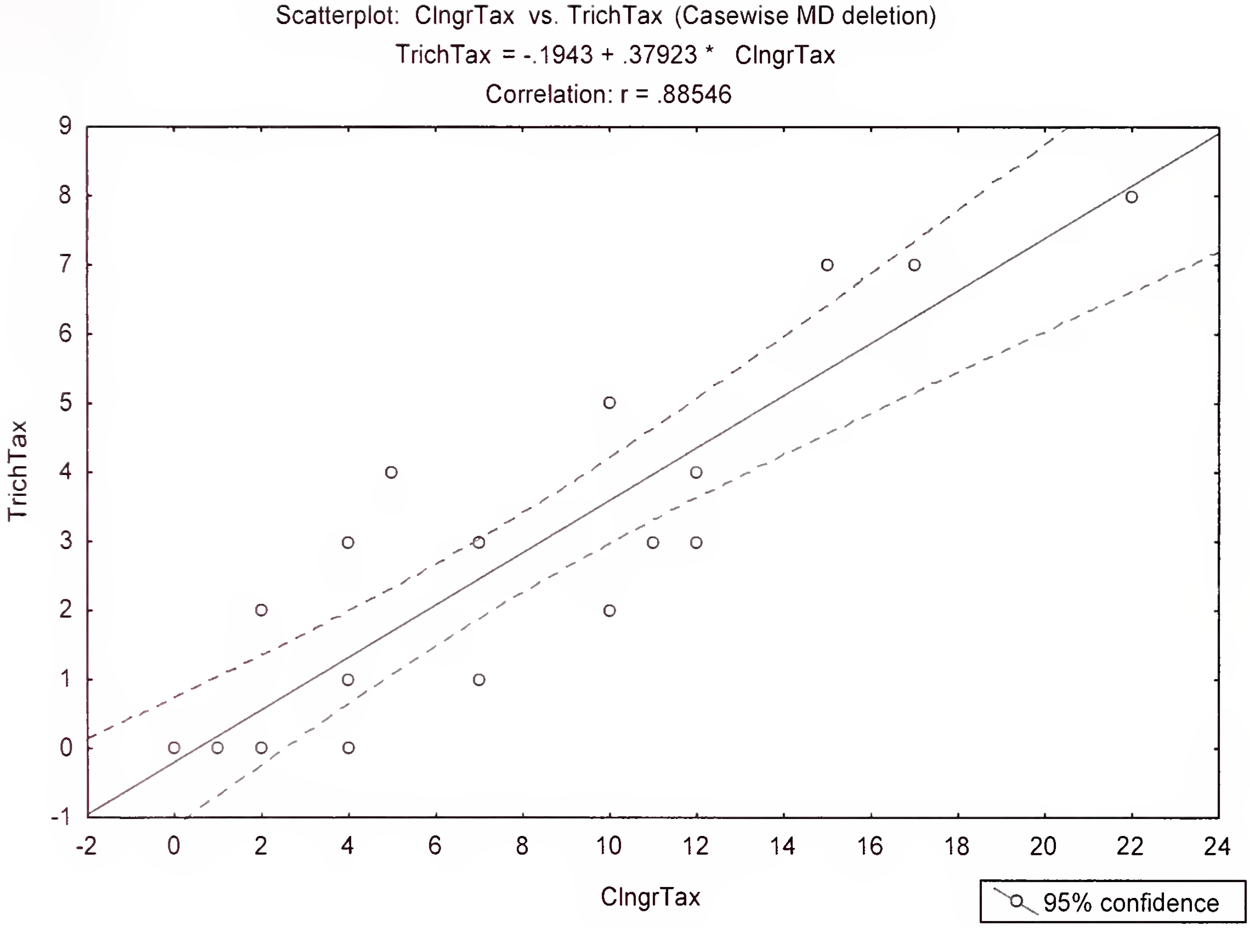


Figure 11: Scatter plot showing the relationship between Clinger Taxa and Trichoptera Taxa for blackwater streams of the southern plains (Ecoregion 65).

There was a positive correlation (.88) between the Clinger Taxa and the Trichoptera Taxa; the two metrics being redundant and contributing similar information. One of the metrics was selected for final macroinvertebrate index formation.

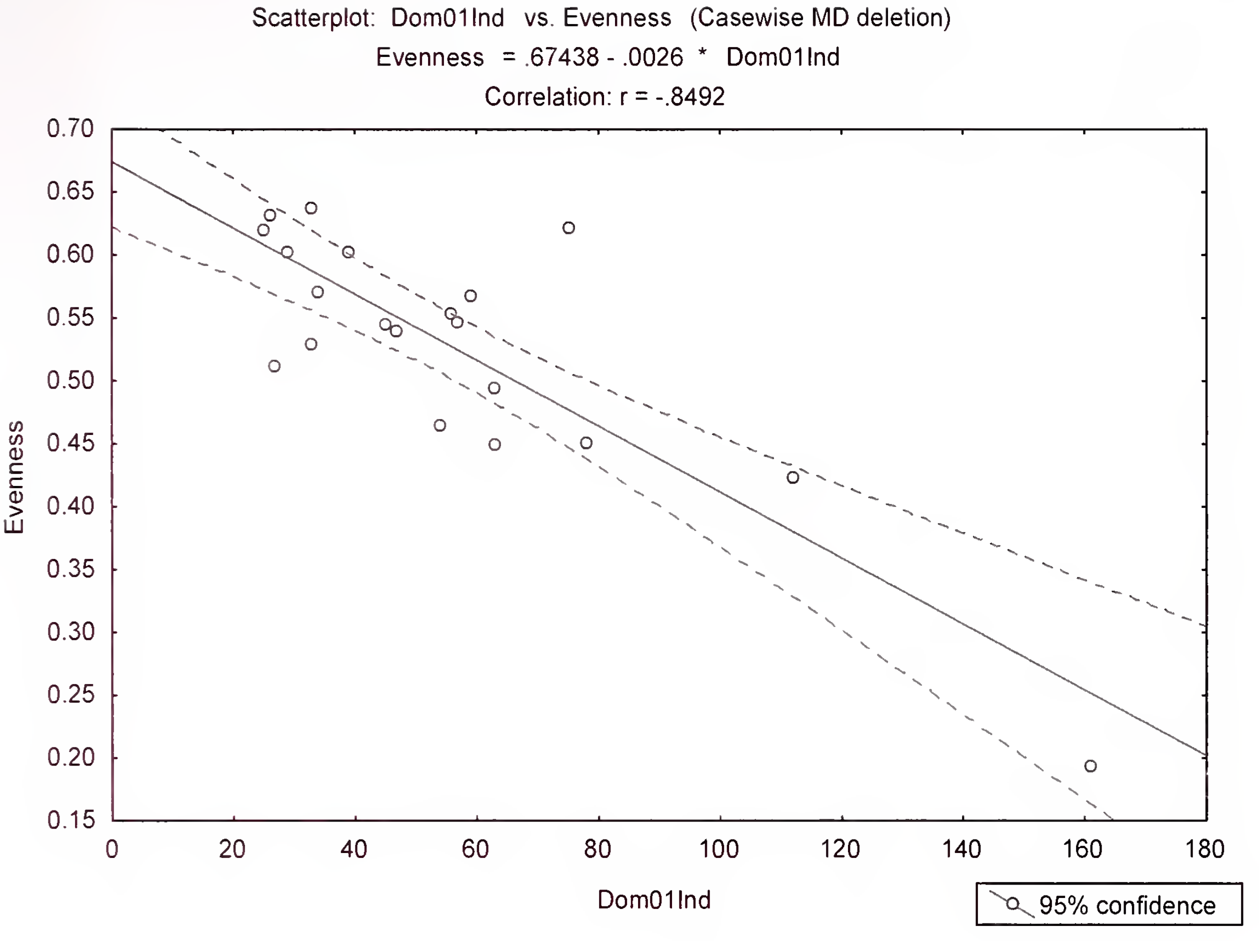


Figure 12: Scatter plot showing the relationship between Evenness and Dominants in common (individuals in one abundant taxa)

There was a strong negative correlation (-0.84) between the Dominants in common (individuals in one abundant taxa) and Evenness values. Both of the metrics together would be redundant and cannot be used in one index.

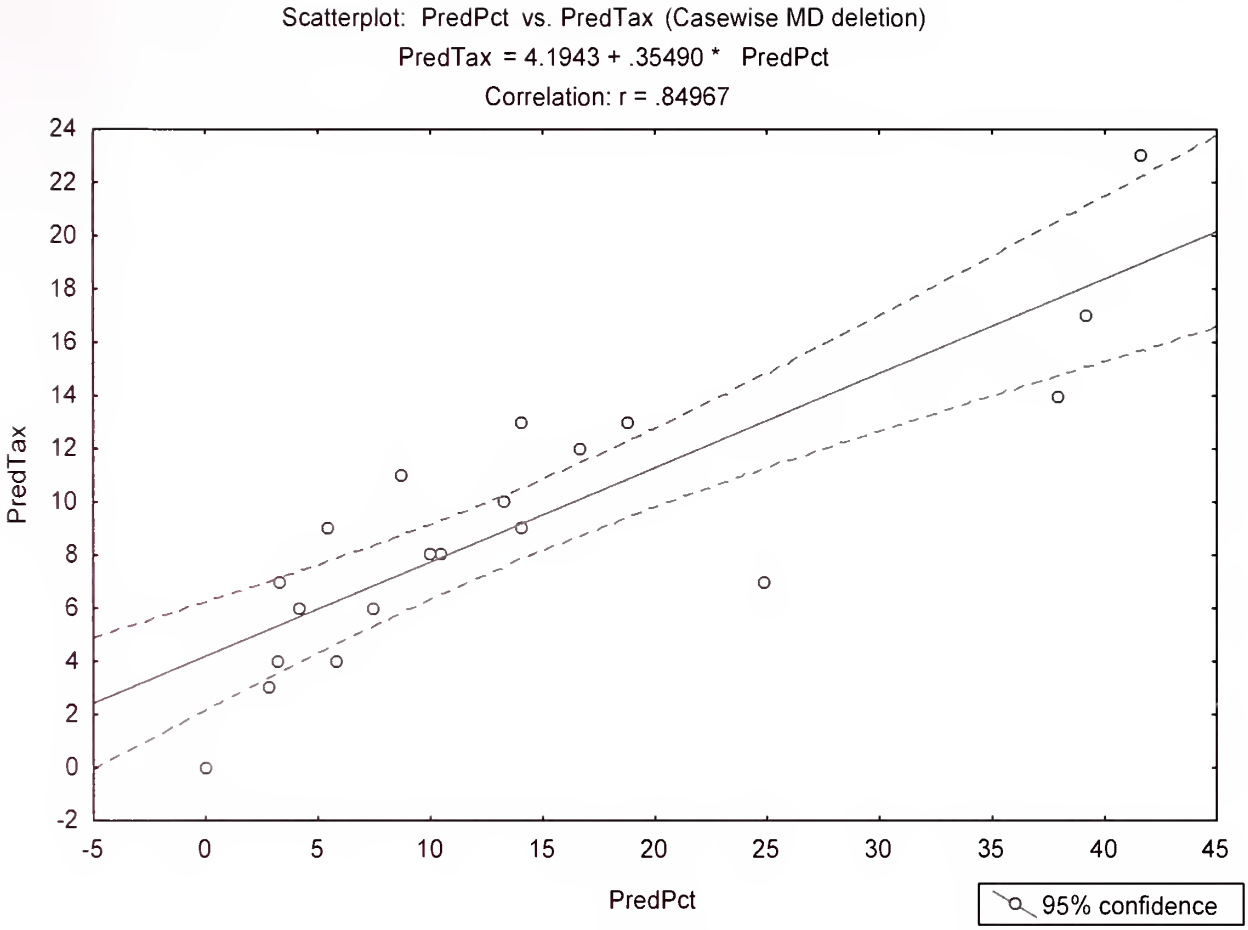


Figure 13: Scatter plot showing the relationship between Predator taxa and Percent Predators for blackwater streams of the southern plains (Ecoregion 65).

There was a strong positive correlation (.84) between Predator percentage and numbers of predator taxa; together being redundant.

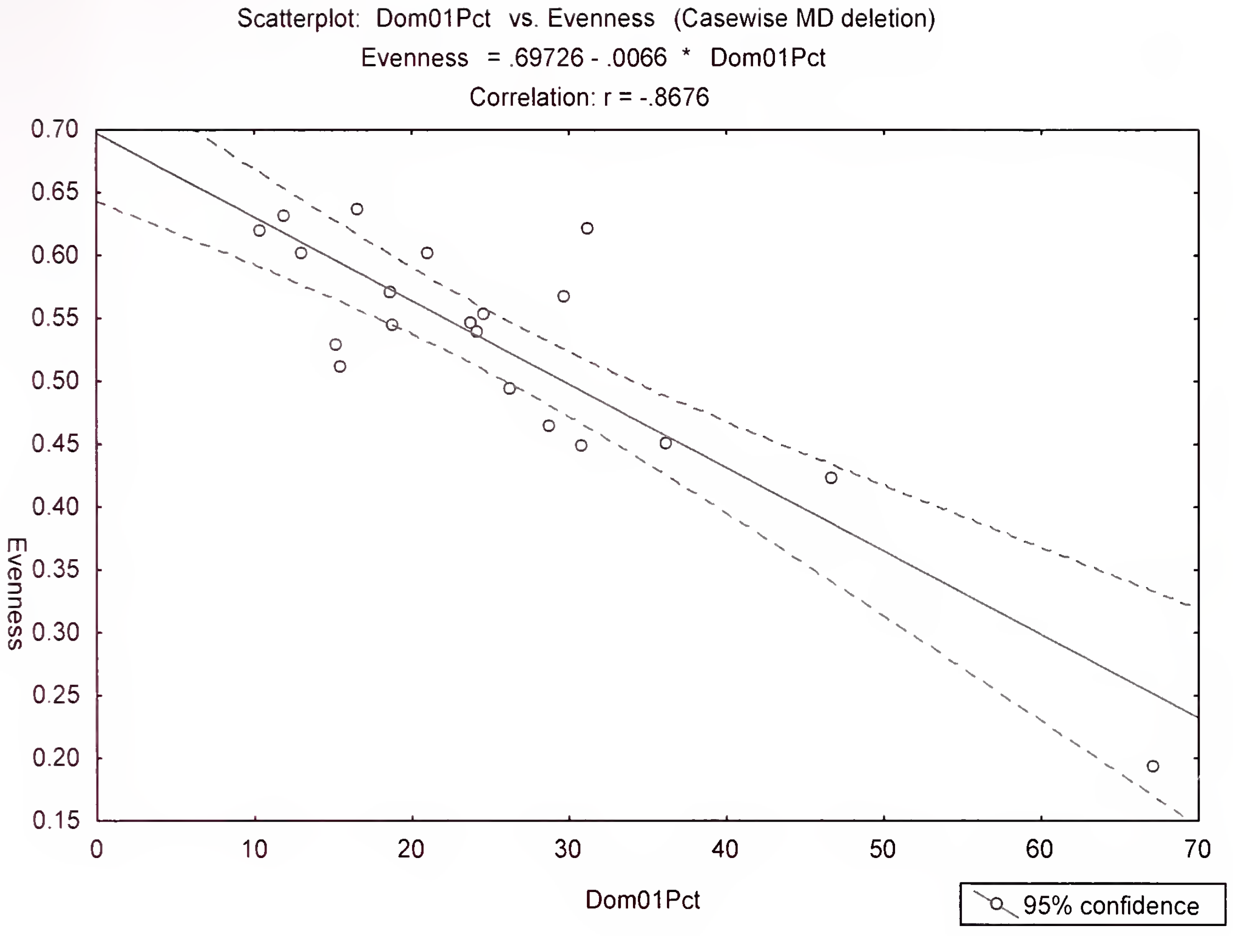


Figure 14: Scatter plot showing the relationship between Evenness and Percent contribution of dominant taxon.

There was a strong negative correlation (-0.86) between the Percent contribution of single dominant taxon and Evenness; being redundant with only one used for index formation.

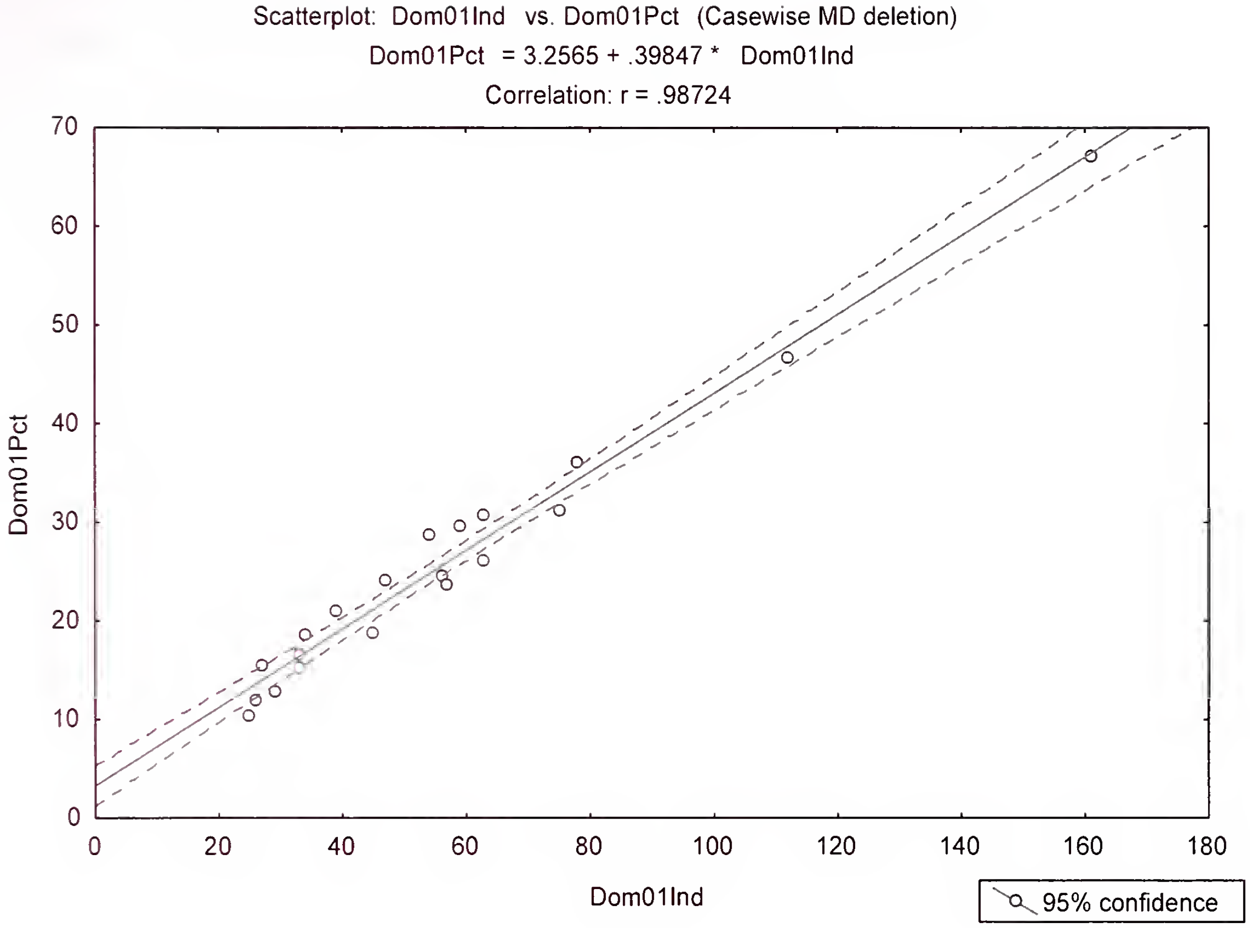


Figure 15: Scatter plot showing the relationship between Dominants in common (individuals in one abundant taxa) and Percent contribution of single dominant taxon for blackwater streams in the southern plains (Ecoregion 65).

It is not surprising that there is a significant positive correlation (.98) and linear relationship between dominance in common taxa (by proportion) and dominance in numbers (common individuals) and the redundancy would bias the index towards a common response mechanism.

Metrics that were candidates for inclusion in the final metrics for southeastern plain blackwater streams belonged to the richness, composition, tolerance/intolerance, functional feeding group and habit measures (table 4.6).

Table 4.6: The metrics that are candidates for inclusion in the final macroinvertebrate index for the southeastern plain (Ecoregion 65) blackwater streams.

Metric category	**Metrics**
Richness measure	EPT Taxa
	Trichoptera Taxa
Composition measure	Diptera Percent
	Cricotopus&Chironomus/Total chironomidae
	Oligochaeta Percent
	Ephemeroptera,Plecopter&Trichoptera Percent
	Ephemeroptera Percent
	Coleoptera Percent
	Trichoptera Percent
Tolerance/Intolerance	Percent contribution of dominant taxon
	Tolerant %
	TolerantTaxa
	Dominants in common(one most abundant taxa)
Functional feeding group	Predator Taxa
	Predator percent
	Filter Taxa
	Fliter Percent
Habit measure	Clinger Taxa

The metrics that had a discrimination efficiency of 50% or greater and were standardized, the scores presented in appendix L.

The final macroinvertebrate index for blackwater streams in the southern plains (ecoregion 65) contained metrics from all categories. The index that best discriminated between impaired and reference streams (with a discrimination efficiency of 75%) is presented in table 4.7 along with a list of metrics that were averaged to form the index value for each stream (table 4.8).

Table 4.7: Southeastern plain ecoregion blackwater (BW) streams macroinvertebrate index value. Imp = impaired, Ref = reference.

Southeastern plain Ecoregion Blackwater Stream Index			
StationID	**Condition**	**Imp & Ref**	**Index**
65o-22	BW_Imp	Impaired	38
65l-423	BW_Imp	Impaired	41
65l-420	BW_Imp	Impaired	44
65l-379	BW_Ref	Reference	45
65l-342	BW_Ref	Reference	49
65g-83	BW_Ref	Reference	52
65o-25	BW_Ref	Reference	53
65h-209	BW_Ref	Reference	55
65g-82	BW_Ref	Reference	58
65l-343	BW_Ref	Reference	64
65h-202	BW_Ref	Reference	64
HH26	BW_Ref	Reference	67
65c-89	BW_Ref	Reference	67
65o-23	BW_Ref	Reference	71
65h-206	BW_Ref	Reference	74
65o-24	BW_Ref	Reference	76
65l-10	BW_Ref	Reference	80
65c-40	BW_Imp	Impaired	83
HH24	BW_Ref	Reference	83
HH25	BW_Ref	Reference	85

Table 4.8: Metrics that formed the final macroinvertebrate index - southeastern plains (Ecoregion 65) blackwater reference streams

Metrics that formed the final Index - southeastern plain ecoregion blackwater streams
Percent Diptera
Cricotopus & Chironomus/Total Chironomidae
Filter Taxa
Ephemeroptera Plecoptera & Trichoptera (EPT) Taxa
Tolerant Taxa
Percent Oligochaeta

Box and whisker plots discriminating impaired blackwater and reference blackwater sites are presented in Figure 16.

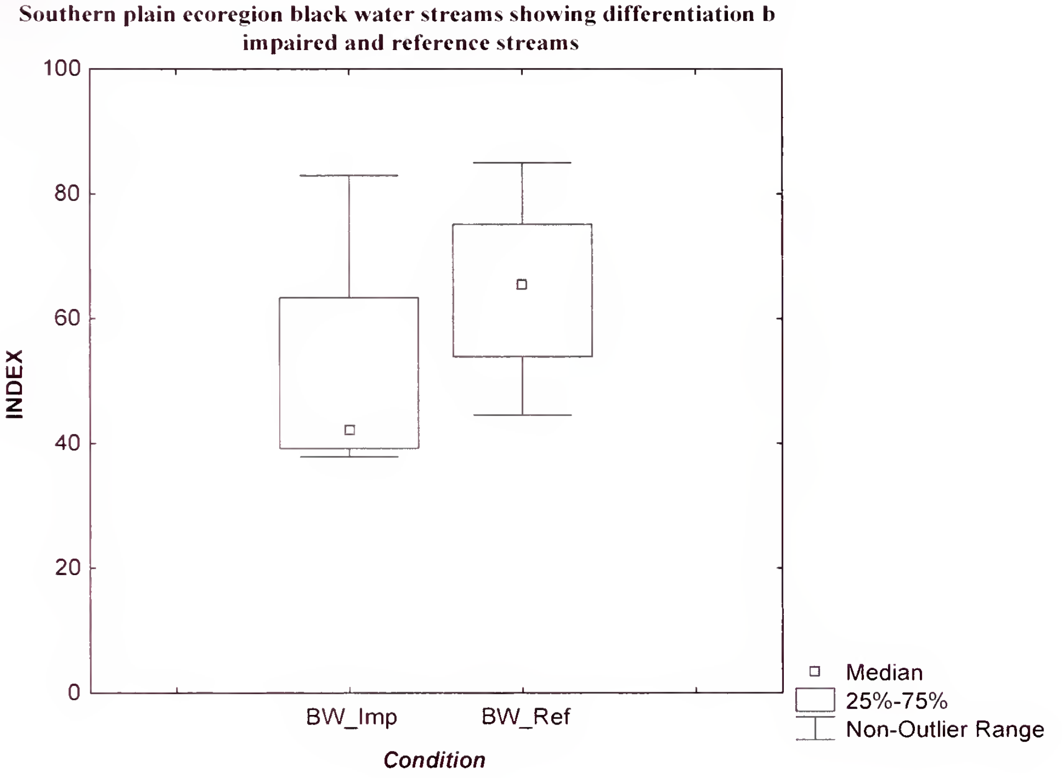


Figure 16: Index differentiating impaired streams and reference blackwater streams in the southern plains (Ecoregion 65).

Southeastern plain ecoregion blackwater reference streams scored a value of 55 at 25^{th} percentile. Among impaired Southeastern plain ecoregion blackwater streams 75% of the streams had scores below the 25^{th} percentile for the reference streams; the median of the reference streams being above the 75^{th} percentile of impaired streams.

Southeastern Plain (Ecoregion 65) clearwater streams

Of all the twenty southeastern plain clearwater streams, the metrics that discriminated the 15 clearwater reference stream sites from the 35 clearwater impaired

streams, and had discrimination efficiencies of 50% or greater are listed in appendix M; the metrics and their corresponding discrimination efficiencies being presented in table 4.9.

Table 4.9: Metrics with discrimination efficiency of 50% or greater in southeastern plain (Ecoregion 65) clearwater streams.

	Metrics	DE
Clearwater streams	Crustacean Molluscan Taxa	60
	Amphipoda Percent	63
	Oligochaeta Percent	63
	BeckBI	60
	Scraper Taxa	69

The correlation analysis of the selected metrics showed no redundancies (Table 5) among the five metrics.

Table 5: Pearson product correlation coefficient of southeastern plain (Ecoregion 65) clearwater streams

Pearson product correlation coefficient of clearwater streams					
	CrMolTax	Amphipoda	Oligochaeta	BeckBI	Scraper Taxa
CustaceanMolluscan Taxa	1.00				
Amphipoda Percent	0.01	1.00			
Oligochaeta Percent	0.22	-0.02	1.00		
BeckBI	-0.23	-0.17	-0.44	1.00	
Scraper Taxa	0.61	-0.01	-0.19	0.07	1.00

The candidate metrics for the final macroinvertebrate index of clearwater streams in the southeastern plain belonged to the richness, composition, tolerance/intolerance values, and functional feeding group measures (table 5.1); standardized scores for the metrics that formed the index being presented in appendix N. The final index value of each stream presented in table 5.2.

Table 5.1: The candidate metrics inclusion in the final macroinvertebrate index for southeastern plain (Ecoregion 65) clearwater reference streams.

Metric category	**Metrics**
Richness	Crustacean Molluscan Taxa
Composition measure	Amphipoda Percent
	Oligochaeta Percent
Tolerance/intolerance	BeckBI
Functional feeding group	Scraper taxa

Table 5.2: Macroinvertebrate index value for southeastern plain (Ecoregion 65) clearwater (CW) streams. Imp = impaired, Ref = reference.

Southeastern plain Ecoregion Clearwater streams Index			
Station ID	**Condition**	**Imp& Ref**	**Index**
65g-14	CW_Imp	Impaired	20
65d-1	CW_Imp	Impaired	25
65g-69	CW_Imp	Impaired	30
65g-4	CW_Imp	Impaired	31
65g-130	CW_Imp	Impaired	31
65g-8	CW_Imp	Impaired	31
65g-10	CW_Imp	Impaired	34
65c-4	CW_Imp	Impaired	35
65g-135	CW_Imp	Impaired	36
65g-137	CW_Imp	Impaired	37
65g-17	CW_Imp	Impaired	39
65c-5	CW_Imp	Impaired	43
65k-85	CW_Ref	Reference	43
65o-12	CW_Ref	Reference	44
65k-129	CW_Imp	Impaired	47
65c-88	CW_Imp	Impaired	47
65k-54	CW_Ref	Reference	48
65h-34	CW_Imp	Impaired	48
65h-203	CW_Ref	Reference	49
65h-32	CW_Imp	Impaired	49
65k-128	CW_Imp	Impaired	51
65o-18	CW_Imp	Impaired	52
65o-11	CW_Imp	Impaired	52
65k-56	CW_Ref	Reference	54
65c-3	CW_Imp	Impaired	55
65d-3	CW_Ref	Reference	56
65k-55	CW_Ref	Reference	58

65c-8	CW_Imp	Impaired	58
65k-68	CW_Ref	Reference	58
65d-21	CW_Imp	Impaired	59
65d-20	CW_Imp	Impaired	59
65d-18	CW_Ref	Reference	59
65k-37	CW_Imp	Impaired	60
65d-4	CW_Ref	Reference	61
65d-39	CW_Imp	Impaired	62
HH29	CW_Ref	Reference	62
65d-32	CW_Imp	Impaired	65
65c-12	CW_Imp	Impaired	67
65d-14	CW_Ref	Reference	67
65L-184	CW_Imp	Impaired	68
65h-174	CW_Imp	Impaired	69
65k-102	CW_Imp	Impaired	70
65l-391	CW_Imp	Impaired	70
65g-62	CW_Ref	Reference	73
65l-381	CW_Ref	Reference	73
65c-80	CW_Ref	Reference	75
65h-41	CW_Imp	Impaired	75
65h-17	CW_Imp	Impaired	80
65k-113	CW_Imp	Impaired	82

Metrics that formed the final macroinvertebrate index values have a discrimination efficiency of 73 between impaired and reference clearwater.

The box and whisker plots illustrating discrimination between impaired and reference clearwater streams are presented on Figure 17.

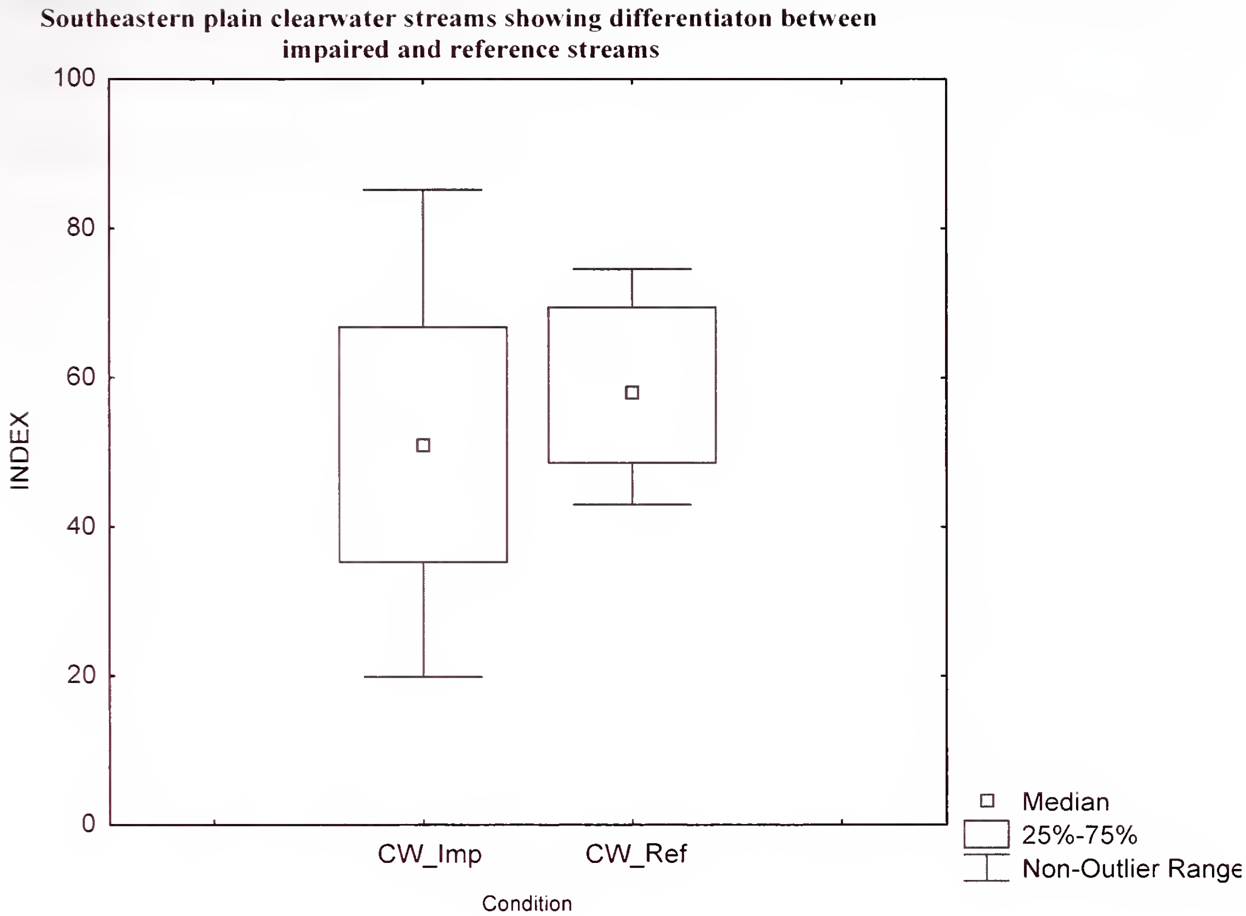


Figure 17: Index differentiating reference and impaired clearwater streams in the southeastern plain (Ecoregion 65).

The macroinvertebrate index score for the clearwater reference streams of the southeastern plain ecoregion had a score of 51 at the 25th percentile. Forty-nine percent of the impaired streams scored below the 25th percentile for reference streams. There was a distinctive overlap between reference and impaired streams; medians of the impaired and reference streams were also overlapping (figure 17).

Principal Components Analysis of selected metrics of blackwater and clearwater streams of southeastern plains revealed that both stream types were randomly placed in the ordination space (figure 18) and a cluster of clear water streams encircling

blackwater streams; 65o-12 having the highest concentration of iron and phosphorus while HH29 had the highest concentration of copper. The reference metrics used for PCA ordination are listed in appendix O.

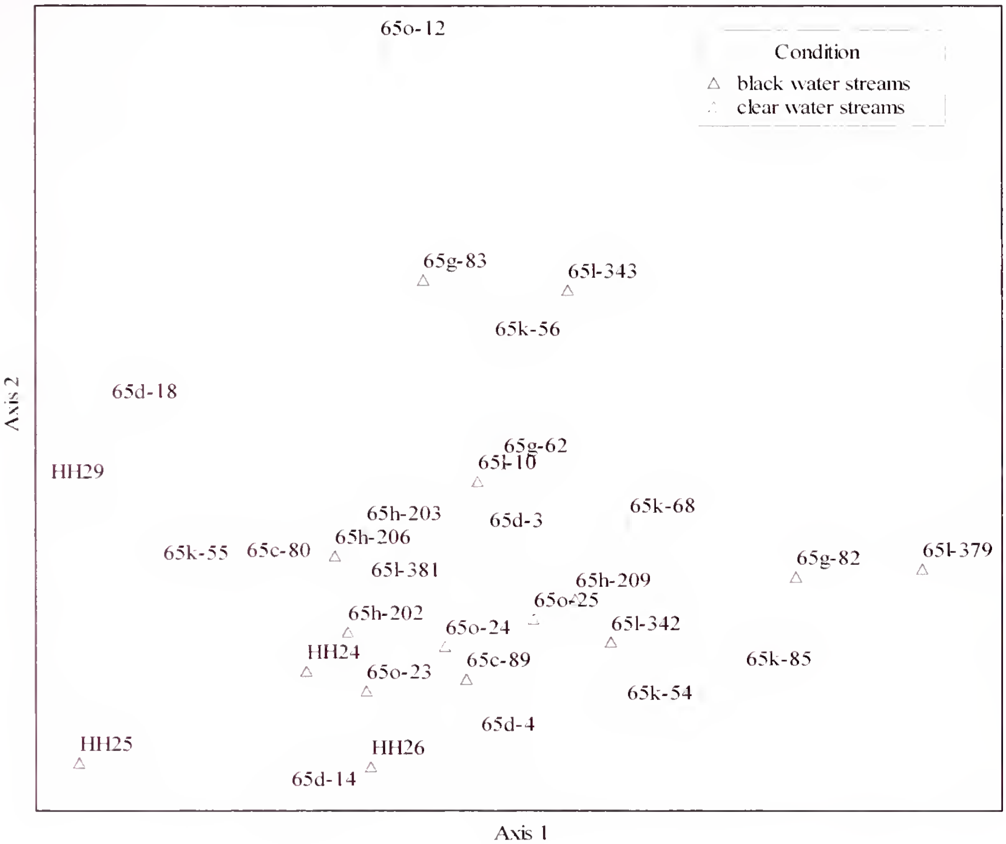


Figure 18: PCA ordination showing clusters of clearwater and blackwater reference streams in the southeastern plain (Ecoregion 65)

DISCUSSION

Chemical and physical data indicated observable differences between blackwater and clearwater streams in both ecoregions. Alkalinity, pH and hardness were higher in clearwater streams than in blackwater streams. The range of total physical habitat scores for blackwater streams was greater in both ecoregions, being typical broad flood plains as suggested by Benke and Meyer (1988).Riparian influences increase rather than decrease along the continuum in the blackwater rivers (Edwards and Meyer 1990).

The substrate of the blackwater streams is dominated by sand as previous studies by St. John and Anderson (1982) noted. Particle size is an important factor in determining community structure in streams (Minshall 1984). Sandy sediments are strongly dominated by gathering collectors (oligochaetes and chironomids) (Benke and Meyer 1988) in black Macroinvertebrates data indicate that there is a substantial diversity of macroinvertebrates in the blackwater streams. The mayfly, *Stenonema,* is common in blackwater streams (Meyer 1900). The other productive components are the collector-gatherers. Chironomids (*Nanaocladius, Kiefferulus, Polypedilum illinoense, Stenochironomus, Polypedilum tritum, Tvetenia, Tribelos*) and oligochaeta are well represented in blackwater streams (Benke *et al.* 1984, Smock *et al.* 1985 and Stites 1986). Filterfeeders (*Polypedilum, Dicrotendipes, Simulidae, and Isonychia*) are also well represented in the blackwater streams Smock *et al.* 1985). Scrapers are rare in blackwater streams (Benke *et al.* 1984, Smock *et al.* 1985, Smock and Roeding 1986) according to their studies.

Each metric is expected to contribute relevant and necessary ecological information to the creation of a useful bioassessment tool. Aggregation of metric scores simplifies management decisions so that a single index value can be used to determine whether corrective action is required. Index scores for reference blackwater streams and clearwater streams were compared to the index score of reference streams in both the southeastern plain ecoregion (65) as well as the southern coastal plain ecoregion (75). Further on the stream sites were given narrative ratings (stream health and need for restoration) based upon the individual index scores. The narrative ratings and the index score together could provide elucidating information on the need for a different set of reference conditions for the two ecologically different stream types.

Measures of composition describe the stream`s macroinvertebrate assemblage (identity, key taxa and abundance) and the relative contribution of populations to the total fauna (Barbour *et al.*1996). When considering all stream types together, compositional metrics had a high discrimination efficiency in the southern coastal plain streams (ecoregion 75), with percent Tanypodinae, percent odonata, percent oligochaeta, percent amphipoda and percent noninsect taxa aggregated to form the final macroinvertebrate index .The noninsect invertebrates were detritivores that feed on CPOM and are extreme trophic generalists (Anderson and Sedell 1979) whereas Oligochaeta were primarily gathering collectors.

For Southern coastal plain (ecoregion 75) clearwater streams, the metrics that successfully formed the final macroinvertebrate index were dramatically different, with the aggregate index coming from compositional metrics, (percent tanypodinae/total Chironomidae, percent amphipoda, percent noninsect taxa, percent Cricotopus &

Each metric is reflected as [illegible]

information to the creation of [illegible]

simplifies management [illegible]

whether correct [illegible]

observed site [illegible]

sample scale [illegible]

[illegible]

For Montana [illegible]

successfully refined the final measurement index were dramatically different, with the aggregate index coming from compositional metrics (percent Rhyacophilidae(?), Chironomidae, percent amphipoda, percent noninsect taxa, percent Cricotopus &

chironomus/Total chironomidae) and functional feeding groups (predator taxa and collector taxa). In the case of the southern coastal plain clearwater reference stream, hundred percent (100%) of the impacted stream sites fell below the 25th percentile of reference sites (figure 6).Of the southern coastal plain reference streams, 75% of the streams are classified in the good category (figure 4).Eighty-five percent of impaired sites scored below the 25th percentile of southern coastal plain reference sites. In the same manner that narrative assessments were created for all wadeable streams in Georgia (Gore *et al.* 2005), the narrative assessments using index values for all the southern coastal plain reference streams (table 5.3) and southern coastal plain clearwater reference streams (table 5.4) were created and compared . A comparison of Southern coastal plain (ecoregion 65) clearwater impaired and reference streams narrative ratings are presented in figure 19. Figure 20 is showing percentage of southern coastal plain (ecoregion 65) clearwater reference streams classified by the final macroinvertebrate index in each category. Using the final macroinvertebrate index, no reference streams were classified as being impaired (fig 20). In Pie chart Figure 21, showing Percentage of Southern coastal plain (ecoregion 75) reference streams classified by the final macroinvertebrate index in each category.

Table 5.3: Definitions of narrative assessments using index values

Southern coastal plain (ecoregion 65) reference streams

	Percentile of reference index values	Index value
Very Good		≥89
Good	≥25th	78-88
Fair	≤25th	50-77
Poor		26-49
Very Poor		≤26

Table 5.4: Definitions of narrative assessments using index values

Southern coastal plain (ecoregion 65) clearwater reference streams

	Percentile of reference index values	Index value
Good	≥25th	≥100
Fair	≤25th	67-99
Poor		33-63
Very Poor		≤33

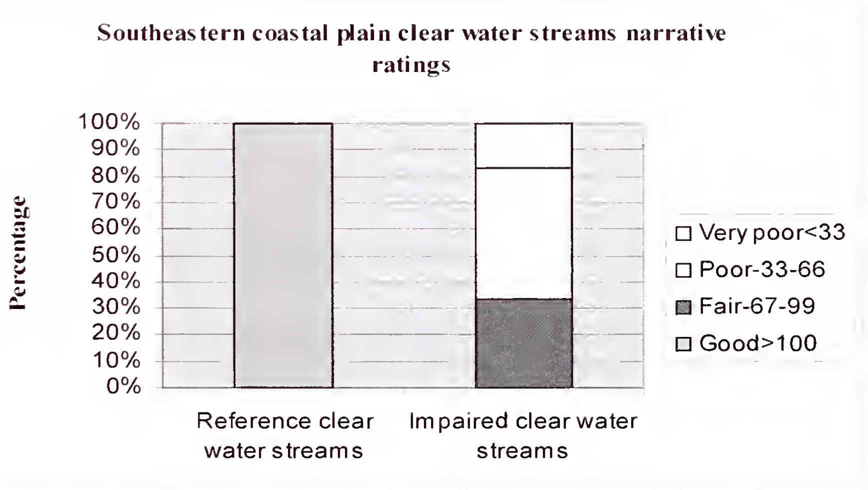


Figure 19: Southern coastal plain (ecoregion 65) clearwater impaired and reference streams narrative ratings – a comparison

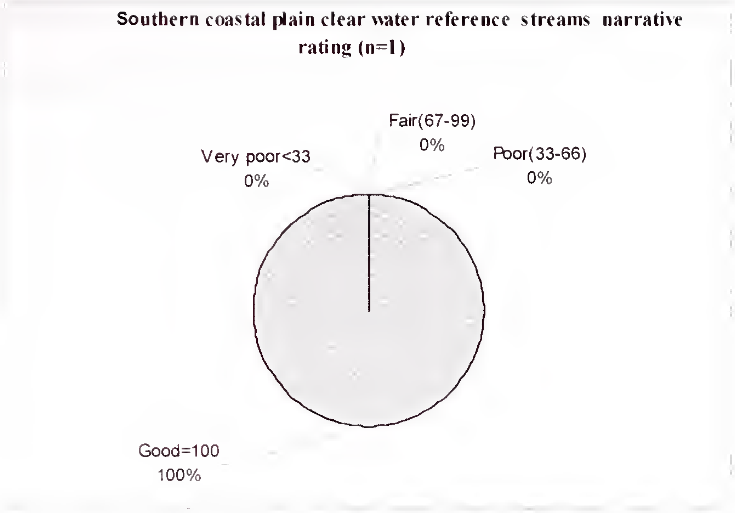


Figure 20: Pie chart showing percentage of southern coastal plain (ecoregion 65) clearwater reference streams classified by the final macroinvertebrate index in each category.

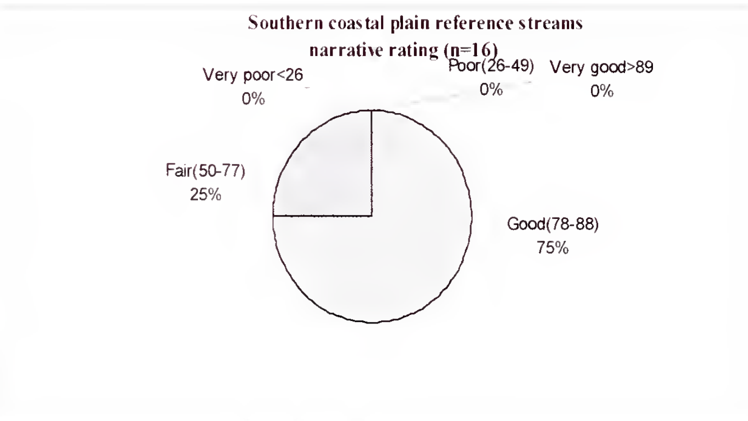


Figure 21: Pie chart showing Percentage of Southern coastal plain (ecoregion 75) reference streams classified by the final macroinvertebrate index in each category

When considering southern coastal plain blackwater reference streams, a score of 81 occurred at the 25th percentile. Those streams with scores equal or greater than the 25th percentile of the reference stream are classifed as "good" and "very good" for streams

have a score ranging from from 81 to100. Of the 13 impaired stream sites, 86% scored below the 25th percentile of the blackwater reference stream.

Blackwater streams of the southern coastal plain (ecoregion 75) scored higher ("good" and "very good" categories). This accounts for eighty six percent (86%) of the reference streams. Of the eighty six (86%) of the stream sites, the stream sites that scored ≥91 (very good) were 57%. For a comparison, the blackwater streams index value that have good and very good ratings, ranging from 81-100, and index value of the reference streams having good and very good ratings ranged from 78-88. Blackwater reference streams performed better than the reference streams, in terms of the percentage of streams in good condition and in terms of higher index values. The narrative assessment, using final macroinvertebrate index values based upon blackwater reference streams, is explained with in table 5.5. Blackwater reference streams and impaired streams narrative ratings in percentage are compared (fig. 22) while the percentage of the blackwater reference streams in each category is presented in a pie chart (figure 23).

Table 5.5: Definitions of narrative assessments using index values

Southern coastal plain (Ecoregion 75) blackwater reference streams

	Percentile of reference index values	Index value
Very Good		≥91
Good	≥25th	81-90
Fair	≤25th	53-80
Poor		27-52
Very Poor		≤27

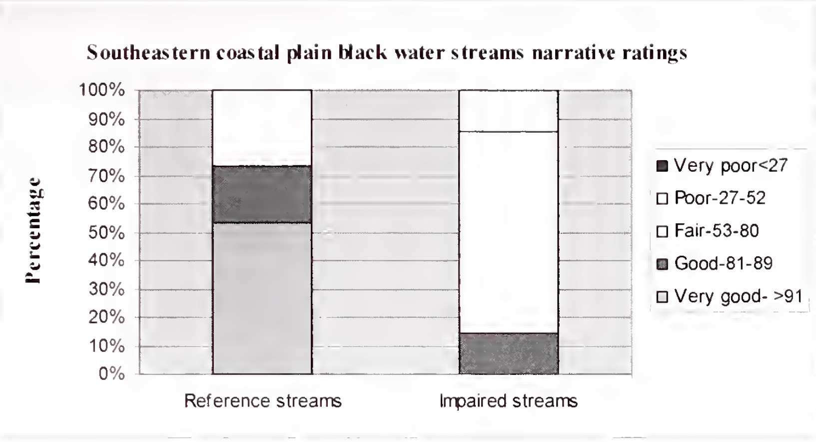


Figure 22: Southern coastal plain (Ecoregion 75) blackwater impaired and reference streams narrative ratings (using a blackwater-specific macroinvertebrate index) –a comparison

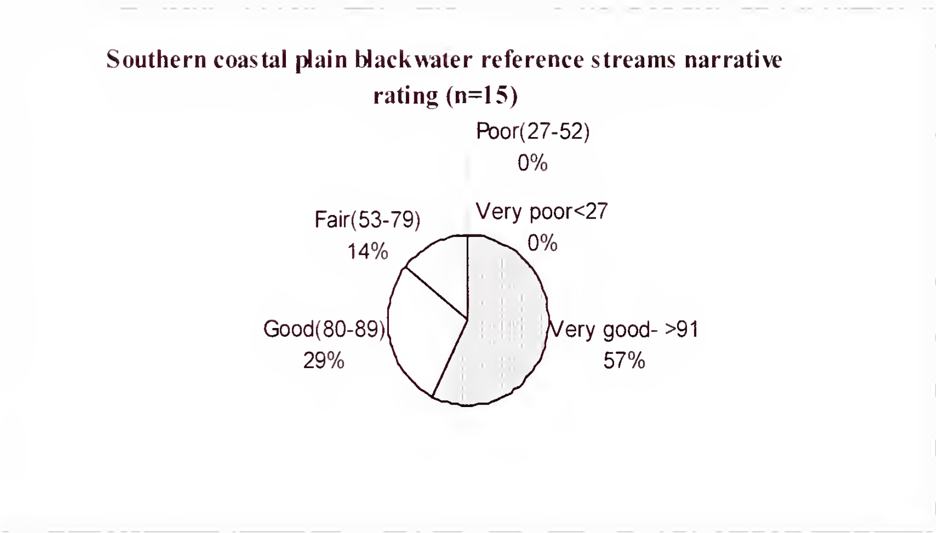


Figure 23: Pie chart showing Percentage of Southern coastal plain (Ecoregion 75) blackwater reference streams in each category when classified using a blackwater-specific macroinvertebrate index.

For southeastern plain streams, metrics that performed better during final index creation formation belonged to the richness measures, compositional measures,

tolerance/intolerance values, functional feeding groups, and habit measures. Richness measures reflect the diversity of the aquatic assemblage (Resh *et al.* 1995) and correlates with the increasing health of the assemblage (Barbour *et al.* 1996). As a richness measure, EPT taxa is a universal metric (Plafkin *et al.* 1989) and the absence of these taxa in streams is an indication of perturbation (Wallace *et al.* 1996, Barbour *et al.* 1996).

For the southeastern plains reference streams, a score of 48 is at the 25th percentile. Reference stream sites that were classified in good and very good category had a range of scores from 48 to100; 74% of reference stream sites have such scores when the macroinvertebrate index was evaluated. Only 6% of stream sites scored higher than the index value of 74. Fifty nine percent of the impaired streams fell below the 25th percentile of the reference condition.

Clearwater streams of the southeastern plains (ecoregion 65) were characterized by a macroinvertebrate index with the selected tolerance and compositional metrics. The southeastern plains clearwater reference streams in the 25th percentile scored 51 or greater. The "good" clearwater streams of the same ecoregion had scores ranging from 51 to 76; comprising 73% of the stream sites. Forty-nine percent of impaired clearwater streams were below the 25th percentile of the clearwater streams reference condition. The interquartile ranges between clearwater streams of the southeastern plain show a great deal of overlap and the median of the reference stream and impaired stream are quite similar. Ten percent of the impaired stream sites were in very good condition using the new clearwater reference index.The narrative assessment using the final

macroinvertebrate index for clearwater reference streams are presented in the table 5.6 and table 5.7 respectively.

There is a high chance of a Type I error (declaring a good site impaired) and Type II error (declaring an impaired site good). That might be a reason why there is no very good category in the clearwater reference stream sites. Clearwater reference streams and impaired streams are compared in figure 24, while figure 25 details the percentage of the narrative rating for all reference streams in the southeastern plain and figure 26 details the percentage of clearwater reference streams in the southeastern plain.

Table .5.6: Definitions of narrative assessments using index values

South eastern plain clearwater reference streams

	Percentile of reference index values	Index value
Very Good		≥77
Good	≥25th	51-76
Fair	≤25th	33 -50
Poor		16-32
Very Poor		≤15

Table 5.7: Definitions of narrative assessments using index values

South eastern plain reference streams

	Percentile of reference index values	Index value
Very Good		≥74
Good	≥25th	48-73
Fair	≤25th	32-47
Poor		16-31
Very Poor		≤16

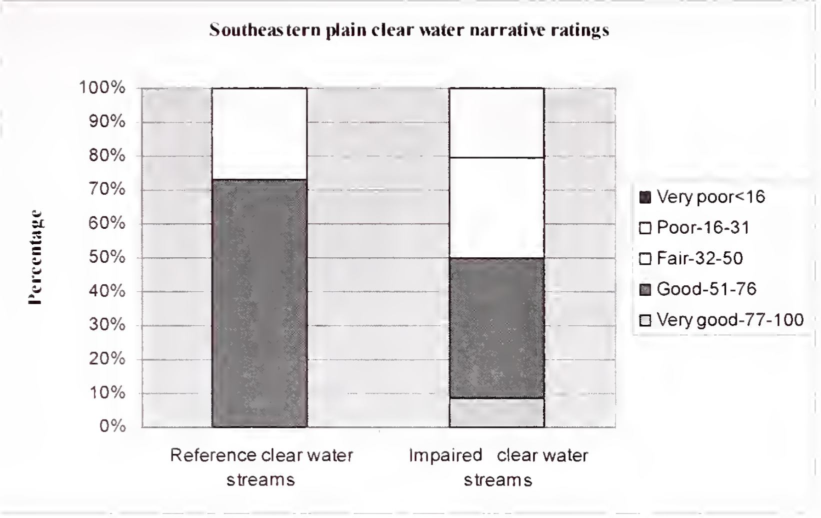


Figure 24: Southeastern plain clearwater impaired and reference streams narrative ratings – a comparison

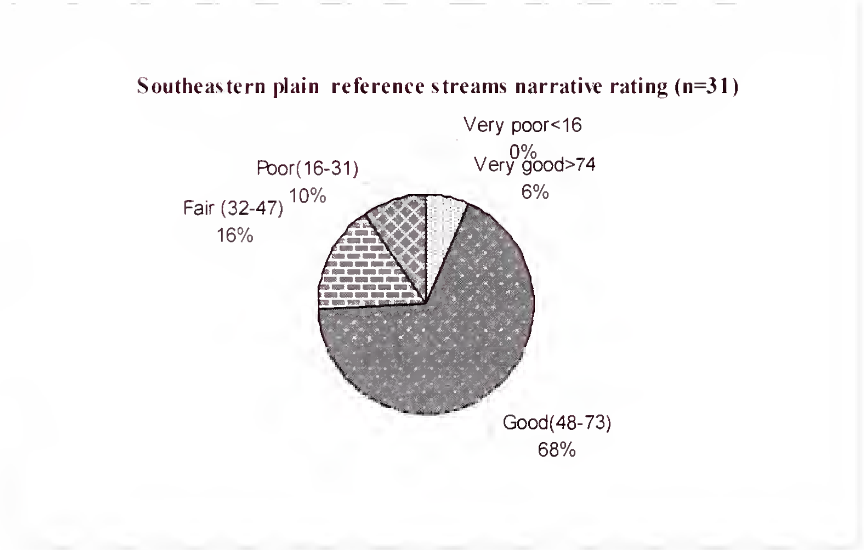


Figure 25: Pie chart showing Percentage of Southeastern plain (Ecoregion 65) reference streams in each category

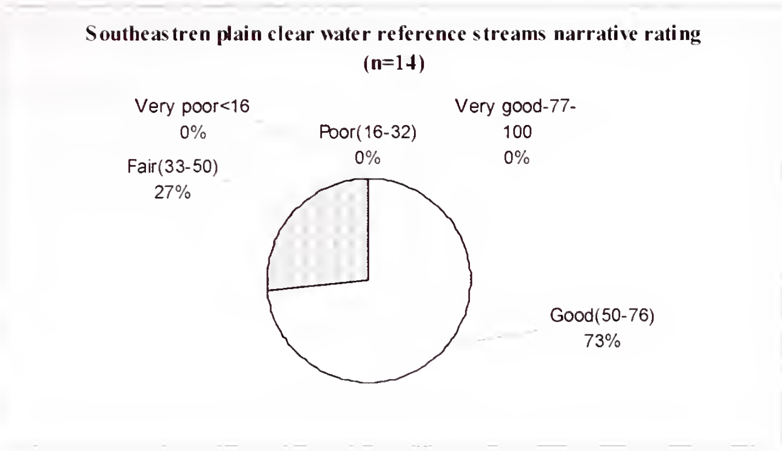


Figure 26: Pie chart showing Percentage of Southeastern plain (Ecoregion 65) clearwater reference streams in each category

Blackwater reference streams of the southeastern plain (ecoregion 65) had a higher index score for each stream site than the reference stream sites of the southeastern plain.A high percentage of filter feeders indicates a healthy coastal plain streams (Beck 1965, Smock *et al.* 1985). Studies have also revealed that the proportion of filter feeders were lower in impaired streams than in the reference streams (Stribling *et al.* 1995, Gerritsen *et al.* 1995). Morpho-behavioral adaptations like the head fans of black flies and coxal-femoral hairs of *Isonychia* and behavioral activities such as net building by caddis flies and midges and body undulations of *Chironomus* aid in filtering (Anderson and Sedell 1979). As primary production increases, the grazer functional-feeding group is expected to increase significantly (Vannote *et al. 1980,* Minshall *et al.*1985). Many Diptera (ptychopterids, some tipulids, psychodids, and many chironomids), oligochaete worms and isopods belong to the collector-gatherer guild (Anderson and Sedell, 1979). Index scores of 55 or greater among southeastern plain blackwater streams were at the 25th percentile and above it. Seventy-five percent of blackwater reference streams scored in the range of 55 to 100. Of that 75%, 19% were in the very good category. The rest

(56%) belonged to "good" categroy with scores from 54 to 76. Using the blackwater macroinvertebrate index, one of the impaired stream sites had a score that categorized it as "very good." Seventy-five percent of the blackwater impaired streams scored below the 25th percentile of the blackwater reference stream sites.

The reference blackwater streams scored 48 the score at the 25th percentile with 74% of the streams scoring from 48 to100; 6% of the streams falling into the "very good" category. The narrative assessment using blackwater stream macroinvertebrate is explained in table 5.8.A comparison of blackwater reference streams and impaired streams narrative ratings presented in figure 27 and the percentage of the narrative rating of the blackwater reference streams in figure 28.

Table 5.8: Definitions of narrative assessments using index values

South eastern plain (Ecoregion 65) blackwater reference streams

	Percentile of reference index values	Index value
Very Good		≥77
Good	≥25th	55-76
Fair	≤25th	36 -54
Poor		18-35
Very Poor		≤18

(56%) belonged to "good" category with scores from 54 to 76 [illegible]

macroinvertebrate index [illegible]

as "very good." Seventy-five percent of [illegible]

the 25th percentile of the [illegible]

The [illegible]

74% of the [illegible]

category. The [illegible]

explained [illegible]

[illegible]

of the [illegible]

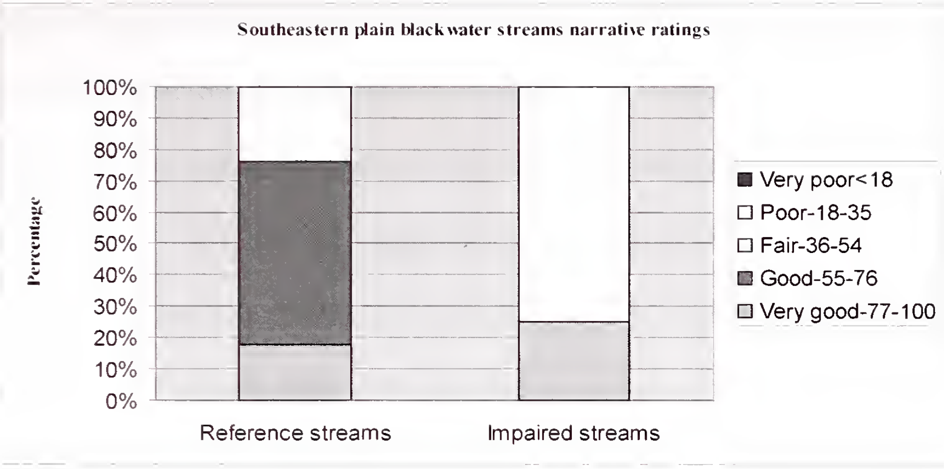


Figure 27: Southeastern plain (Ecoregion 65) blackwater impaired and reference streams narrative ratings using the blackwater macroinvertebrate index – a comparison

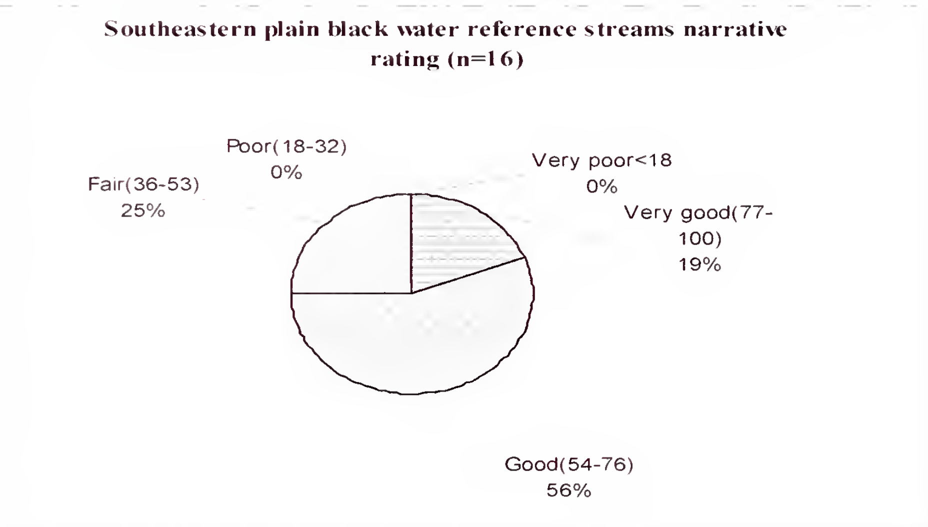


Figure 28: Pie chart showing Percentage of Southeastern plain (Ecoregion 65) blackwater reference streams in each category using the blackwater macroinvertebrate index.

The principal component analysis of the selected metrics showed that the stream sites are scattered in the ordination space, though a few of both stream types tend to cluster, slightly. This is because stream types belong to the fourth order, and common metrics are present in both stream types, it should also be noted that the community structure is correlated to the trophic relationships (Cummins 1975, Cummins 1975). As

per the studies the functional feeding groups is very different for the black water streams than that envisioned by the original RCC (Benke & Meyer 1988). Similarity in the community structure might be the reason why some streams of both clearwater streams as well as blackwater streams are closer in space. However, it is demonstrated that ecoregions with distinctly different land characteristics have streams that are more distinct; transitional regions have transitional characteristics (Whittier *et al.* 1988), where transitional zone flow is decelerated and the river begins to braid and deposit sediment loads (Gore 1994). High hydraulic heterogeneity exists at the zone of transition to lowland streams as the river begins to braid, further downstream the river meanders and forms blackwater and oxbow lakes a diverse flow pattern is noticed (Gore 1994) .As the flow rates are reduced the substrate changes from sand to one dominated by silt and refractory organic matter (Leonard *et al.* 1985), changes in macroinvertebrate composition and production is expected for the streams associated with swamps(Leonard *et al.* 1985). Local combinations of plants within each biome play a role in supporting a different community of aquatic organisms in the different stream types, called association (Herbert Ross 1963).

The macroinvertebrate index performance may also be related to the quality and quantity of reference and stressed sites found in each ecoregion. The amount of variance between reference sites and impaired sites can directly affect the strength of the separation between reference and stressor box plots. In both ecoregions, the blackwater streams discriminated the impaired streams from the reference streams quite well and in both ecoregions the blackwater stream reference streams had high index scores. The more sites available for investigating metric performance, the less potential there is for a few

sites to influence the overall reference and stressed site metric value distributions as with the case of southern coastal plain clearwater streams, which had only one reference stream.When degraded sites are relatively rare, the difference between reference and stressed sites may not be as great as one might expect with a higher number of samples; making it more difficult to evaluate the discriminatory ability of metrics and, as a result, more difficult to choose the best metrics as in the case of southern coastal plain clearwater streams.

It should also be considered that benthic macroinvertebrate community structure has been shown to vary with both stream order (Bruns *et al.*1982, Hawkins and Sedell 1981) and season (Minshall 1981) (Lenat 1983) and the component species of a biotic community may better serve as a reflection of the past rather than present, water chemistry conditions (Vincent and John 1975). The temporal aspect of the streams should be given importance (Sedell and Frogatt 1984; Cummins *et al.* 1984, Cummins 1988) at the same time the temporal patterns of production (Hauer and Benke 1991) require equal importance. The index period which started from September-February includes two seasonal maxima, one seasonal minima and quarter of another seasonal minimum (Lenat 1983).

Food resource partitioning by same functional feeding group is largely temporal and secondarily spatial, *i.e.*, there is a temporal isolation of potential competitors, and in any case if they overlap resource partitioning is accomplished by selective feeding. relative dominance of invertebrate group shifts with differences in available sources of energy (Cummins and Klug 1979) *i.e.*; community structure is correlated with trophic relationships (Cummins 1975, Cummins 1975). Autotrophic communities are the major

food base in spring and summer (Minshall 1978) and the autumn winter food source is detritus and provides a continuous supply of fine particulate organic matter throughout the year (Minshall 1967, Kaushik and Hynes 1971, Cummins 1974, Sedell *et al.* 1974, Vannote *et al. 1*980). Variability in food quality and food quantity along with the seasonal shifts in species composition can obscure the results (Hauer and Benke 1991).

It is also evident from this research that some of the functional groups are represented both in clearwater and blackwater streams, mainly amphipods, isopods and noninsects, coinciding with the idea that the relative position of the stream in its watershed confers some similarities in ecosystem structure and function independent of the local setting of geology, soil and stream side riparian vegetation (Vannote *et al* .1980; Minshall *et al.* 1983, 1985). Higher the primary productivity the grazer functional group is expected to increase significantly (Vannote *et al.*1980, Minshall *et al.*1985) but in the black water streams grazers appeared to function as gatherers on the snag habitat (Wallace *et al* .1987, Benke and Meyer 1988).

CONCLUSION

The blackwater and clearwater streams of the southern coastal plain and the southeastern plain have their own distinct ecological differences; being the pH, habitat score and macroinvertebrate structure and function. The blackwater streams of the southern coastal plain have a characteristic macroinvertebrate index comprised of compositional metrics, whereas the blackwater streams of the southeastern plains have a much more diverse fauna and an aggregate index comprised of compositional, tolerance\intolerance, richness, and functional feeding group metrics. The metrics and the indices were able to differentiate between blackwater reference and impaired streams in both the ecoregions. Clearwater streams of southern coastal plain have compositional and functional feeding groups in the final macroinvertebrate index while, Index quality is the reflection of metrics. The higher performance of the metrics the higher the index. Clear water streams of the southeastern plains had a final aggregate index created from metrics describing composition, tolerance\intolerance, richness, and functional feeding groups. Thus, blackwater and clearwater streams in these ecoregions are characterized by their own unique macroinvertebrate indices comprised of distinctive metric measures and should be used independently to evaluate the condition of that stream type in each of these ecoregions.

Even though the habitat score did not discriminate the stream types and so was not a member in the index, the blackwater streams of both the ecoregions had a high score, result of a descent habitat. According to regional reference condition concept, sets of surface waters of similar habitat type are identified in each ecological region. The stress response of some of the metrics in clearwater and blackwater are different, for

example filter percent increase as perturbation increase, but for a blackwater stream high percent of filter feeder is an indication of healthy stream, which was not mentioned in the Rapid Bioassessment Protocols should be considered.

So in conclusion, the RBP metrics were able to distinguish the two stream types when analyzed separately, but reference criteria of the blackwater stream type that can as well be added to the RBP metrics are suggested below. Separate indices derived from metrics with different stress response for blackwater streams and clear water streams will do a better job .Blackwater streams can have a different set of stress response.

1. Hyphoreic subsystem is the third vertical dimension and it exists below the sediment surface of each of the longitudinal and lateral subsystems in most streams. The hyporheic zone of many streams have invertebrate production rivals that of benthos (e.g., Stanford and Ward 1988, Smock *et al.*1992) and difficult to assess (Palmer 1993). It is an important habitat for numerous aquatic organisms, contains a wide variety of subterranean fauna and zoo benthos at various stages of life cycle (Coleman and Hynes 1970, Stanford and Gauffin 1974, Williams 1984, Smock *et al.* 1992, Stanley and Boulton 1993).
2. Soil core study can be done within the stream at 25, 50 and 75m and in the riparian area of the stream at 0, 50 and 100m., the hyporheic zone can extend up to 2 km laterally from the main stream channel in rivers with coarse gravel beds.
3. Soil core study can be useful for hyphoreic benthic study as well as substitute for pebble count.
4. Meiofauna also are fairly sensitive to various pollutants, and may be useful as indicator species. (Coull and Chandler 1992)

example filter percent increase as permeability increases and the a[illegible]

percent of filter feeder [illegible] [illegible] which can be [illegible]

Rapid Bioassessment Protocols [illegible]

So in conclusion, the [illegible]

when analyzed separately [illegible]

well as added [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

3. Soil core study [illegible] study as well as substitute for percent

cover.

4. Meiofauna also are fairly sensitive to various pollutants, and may be useful as indicator

species (Coull and Chandler 1992).

5. Discouraging snag removal and channelization of these unique rivers (mainly black water streams) is important for the long term management of the black water rivers.
6. Riparian buffer area of the blackwater streams can be greater than or equal to 20m.
7. P/R ratio may be calculated.
8. More stream sites may be evaluated to avoid noise.
9. Habitat assessment during spring season can provide a much detailed description of the vegetation.

REFERENCES CITED

Anderson. A.B., 1981: White-sand vegetation of Brazilian Amazonia. Biotropica. **13**: 199-210.

Anderson. N. H. and J. R. Sedell., 1979: Detritus Processing by Macroinvertebrates in Stream Ecosystems. Annual Review of Entomology. Vol. **24**, Pages 351-377.

Amanda. Lynn. Middleton., 2006: A multimetric benthic index for Georgias wadeable streams. Thesis(M.S) .Columbus State University.

Arens. K.. 1963: As Plantas lenhosas dos campos cerrados como flora adaptada as deficiencies minerais de solo. In Simpopsio sobre o Cerrado, pp. 287-303.Universidade do Sao Paulo. Sao Paulo.

Barbour. M. T.. J. B. Stribling and J. R. Karr.. 1995: Multimetric approach for establishing biocriteria and measuring biological condition. Pages 63-77 in W.S. Davis and T.P. Simon (editors). Biological assessment and criteria. Tools for water resource planning and decision making. Lewis Publishers. Boca Raton. Florida.

Barbour. M. T.. J. Gerritsen, G. E. Griffith, R. Frydenborg, E .McCarron, J. S. White. & M.L. Bastian., 1996: A framework for biological criteria for Florida streams using benthic macroinvertebrates. Journal of the North American Benthological Society. **15**: 185-211.

Barbour. M. T.. J. Gerritsen, B.D. Snyder, and J. B. Stribling., 1999: Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Benfield, E. F., 1997: Comparison of litterfall input to streams. Department of Biology. Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA.

Beck, K. C., Reuter J. H. and Perdue E. M., 1974: Organic and inorganic geochemistry of some coastal plain rivers of the southeastern United States. Geochemica et Cosmochimica Acta. **38**:341-364

Beck, W. M., Jr.1965: The Streams of Florida. Bulletin of the Florida State Museum. **10**(3): 25-63.

Beck, K. C. and Perdue. E. M., 1974: Organic and inorganic geochemistry of some coastalplain rivers of the southeastern United States. Geochemica et Cosmochimica. Vol. **38**, pp 314-364.

Benke, A. C., 1990: Ecosystem characteristics and biological production of southeastern Coastal Plain Rivers. Pp 6-7 in: M.B. Bain (ed.) Ecology and Assessment of Warm water Streams. U.S. Fish Wildl. Serv., Rep. 90 (5).

Benke, A. C., Robert. J. Hunter and F. K. Parrish., 1986: Invertebrate drifts dynamics in a subtropical black water river. Journal of North American Benthological Society. **5**: 173-190.

Benke, A. C., T. C. van Arsdall, D. M. Gillespie, and F. K. Parrish., 1984: Invertebrate productivity in a subtropical black water river: the importance of habitat and life history. Ecol. Monog.**54**:25-63.

Benke, A. C., & Meyer J. L., 1988: Structure and function of a black water river in the southeastern U.S.A. Verhandlungen der Angewandte Vereinigung fur Theoretische und Angewandte Limnologie (in press).

Bishop, J. W., 1973: Limnology of a Small Malayan River, Sungai Gombak. Dr. W.Junk B.V., Publisherd, The Hague.

Bird, G. A., and Narender, K. Kaushik., 1981: Coarse Particulate Organic Matter. P41-68 in: Perspectives in Running Water Ecology.

Boluton, A. J., 1993:.Stream ecology and surface-hyporheic hydrologic exchange: Implications, techniques and limitations. Australian Journal of Marine Freshwater Research .**44**:553-564.

Bott, T. L., Brock, J. T., Dunn, C. S., Naiman, R. J., Ovink, R. W.& Petersen, R. C., 1985: Benthic community meatbolism in four temperate stream systems: an intre-biome comparison and evaluation of the river continuum concept.- Hydrobiologie. **123**:3-45.

Bruns, D. A., Minshall, G.W., Brock, J.T., Cushing, C.E., Cummins, K. W. and Vannote, R.L. , 1982: Ordination of functional groups and organic matter parameters from the middle fork of the Salmon river, Idaho. Freshwat.Invertebr. Biol., **1**(3): 2-14.

Caton, L. W., 1991: Improved subsampling methods for the EPA rapid bioassessment benthic protocols. Bulletin of the North American Benthological society. **8**(3): 317-319.

Carlough, L. A. and Meyer, J. L. (1990) Rates of protozoan bacterivory in three habitats of a southeastern black water river. J.N.American Benthol.Soc., **9**: 45-53.

Coleman, M. J., 1980 and H.B.N.Hynes.1970. The vertical distribution of the invertebrate fauna in the bed of a stream. Limnology and Oceanography **15**: 31-40

Coull, B. C., and G. T. Chandler., 1992: Pollution and Meiofauna: field, laboratory, and mesocosm studies. Oceanography and Marine Biology Annual Reviews .30:191-271

Cudney, M. D., and J. B. Wallace., 1980: Life cycles, micro distribution and production dynamics of six species of net-spinning caddisflies in a large southeastern (U.S.A.) river. Holarct.Ecol.**3**: 169-182.

Cuffney, T. F., 1988: Input, movement and exchange of organic matter within the coastal plain blackwater river floodplain system. Freshwater biology. **19**: 305-320.

Cummins, K. W., 1974: Structure and function of stream ecosystems. Bioscience. **24**: 631-641.

Cummins, K. W., 1975: Macroinvertebrates. See Ref. 18, pp. 170-198.

Cummins, K. W., 1975: The ecology of running waters; theory and practice. In Proc.Sandusky River Basin Symp.Int.Joit. Comm.Int.Ref.Gp.Great Lakes Pollution from Land Use Activities (1976-553-346), ed. D.B.Baker, W.B.Jackson, B.L.Parter, pp.227-93. Washington DC: GPO. 475pp.

Cummins, K. W., and K. Klug., 1979: Feeding ecology of stream invertebrates. Annu.rev.Ecol.Syst. **10**:147-172.

Cummins, K. W., G. W. Minshall, J. R .Sedell and R. C. Peterson., 1984: Stream ecosystem theory Verh.Int. Verein.Limnolo.**22**:1818-27.

Cummins, K. W., 1988: Study of stream ecosystems: a functional view. In Pomeroy. L. R. and J.J. Albert eds. Concepts of ecosystem ecology. Springer-Verlag. New York.

Cummins, K. W., Petersen, R. C., Howard, F. O., Wuycheck, J. C., Holt, V. I., 1973: The utilization of leaf litter by stream detritivores, Ecology. **54**:336-45.

Cummins, K. W., J. R. Sedell, F. J. Swanson, G. W. Minshall, S. G. Fisher, C. E. Cushing, and R.C. Petersen., 1984: Stream ecosystem theory. Proceedings of the International Association of Theoretical and Applied Limnology. **22**: 1818-1827.

DeShon. J. E., 1995: Development and application of the invertebrate community index (ICI). Pages 217-243 in W.S.Davis and T. P. Simon (editors). Biological assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers. Bacon Raton. Florida.

Edwards. R. T.. 1985: The role of seston bacteria in the metabolism and secondary production dynamics of southeastern black water rivers. - Ph.D.diss.Univ. Of Georgia. Athens. GA.. U.S.A.

Edwards, R. T.. 1987: Sestonic bacteria as a food source for filtering invertebrates in two southeastern black water rivers. Limnol.Oceanogr. **32**: 221-234.

Edwards. R. T.. & Meyer. J. L.. 1987b: Metabolism of a sub-tropical low gradient black water river. - Freshwat. Biol. **17**: in press

Edwards. R. T.. & Meyer. J. L., 1987a: Bacteria as a food source for black fly larvae in a black water river.J.North..Am.Benthol.Soc. **6**:241-250.

Edwards. R. T. and Meyer. J. L., 1990: Ecosystem metabolisms and turnover of organic carbon along a black water river continuum.

Faith. D. P.. P. R. Minchin & L. Belbin. 1987: Compositional dissimilarity as a robust measure of ecological distance.Vegetatio **69**: 57-68

Fisher. S. G.. & Likens G. E., 1973: Energy flow in Bear Brook, New Hampshire. An Integrative approach to stream ecosystem metabolism. Ecol.Monogr. **43**, 421-439.

Fisher, S.G.. 1977: Organic matter processing by a stream-segment ecosystem: Fort River. Massachusetts. U.S.A. Int.Rev.Hydrobiolo.**62**:701-727.

Fittkau. E. J.. 1964: Remarks on limnology of central-Amazon rainforest streams. Verh.Int.Ver.Limnol. **15**: 1092-96.

Flaig. W.. Beutelspracher. H. Rietz. E., 1975. Chemical composition and physical properties of humic substances. (in :) soil components. J.E.Gieseking (ed.), Springer. New York. **1**,211pp.

Fore. L. S.. J. R. Karr. and R.W.Wisseman., 1996: Assessing invertebrate responses to human activities: Evaluating alternative approaches. Journal of North American Benthological society **15**(2): 212-231.

Gallant. A. L., Whittier, T. R., Larsen, D. P., Omernik, J. M.. Hughes, R. M., 1989: Regionalization as a tool for managing environmental resources. Corvallis,

OR: US EPA. Environmental Protection Agency. Publication nr EPA-600-3-89-060.169p.

Georgia Department of Natural Resources. 1999: (GAEPD).SOP Number: FLD (GERS) 001.

Gerritsen. J., J. S. White. E. W. Leppo. J. B. Stribbling. and M. T. Barbour.1995. Examination of the effects of habitat quality. land use and acidification on macroinvertebrate communities of coastal plain streams. Report # CBWP-MANTA-TR-95-2.Maryland department of Natural Resource. Chesapeake Bay and Watershed Programs. Annapolis. Maryland.

Gillespie. D. M.. Stites. D. L. & Benke. A. C.. 1985: An inexpensive core sampler for use in sandy substrata. – Freshwat. Invertebr.Biol.**4**: 147-151.

Gjessing. E. T.,1976: Physical and Chemical Characteristics of Aquatic Humus. Ann Arbor Sci. Publ .Inc. Ann Arbor. Michigan.

Goodall. D. W. 1954.Objective methods for classification of vegetation. III. An essay in the use of factor analysis. Australian Journal of Botany **2**:304-324.

Gore. J. A.. 1994: "Response of Aquatic Biota to Hydrological Change". Reprinted in "River Biota". Geoffrey Petts and Peter Calow. eds. Blackwell Science Ltd.

Gore. J. A.. J. R. Olson.. D. L. Hughes.. M. Brossett. 2004: Reference Conditions for Wadeable Streams in Georgia with a Multimetric Index for the Bioassessment and Discrimination of Reference and Impaired Streams. Georgia Department of Natural Resources. Atlanta. GA (625 pp.)

Gore, J.A.. A. Middleton, D.L. Hughes., U.K. Rai., and P.M., Brossett: 2005.A Numerical Index of Health of Wadeable Streams in Georgia using a Multimentirc Index for Benthic Macroinvertebrates. Georgia Department of Natural Resources, Atlanta, GA (323 pp.)

Greenland. D.. 1965a: Interaction between clays and organic compounds in soils. Soils and Fertilizers. **28**: 415-521.

Griffith.G.E..Omernick.J.M..Comstock.J.A..Lawrence.S.,Martin,G., Geddard,A..Hulchjer,V.J.. Fostr, (Color poster map, desriptive text, survey tables. and photographs): Reston. Virginia. U.S.Geological Survey. (1:1,700,000 scale).

Hardon, H.J.. 1936: Podzol profiles in tropics. Natuurk. Tijdschr. Ned.-Indie. **96**: 25-41.

Hardon.H.J.,1937:Padangsoil,anexampleofPodzolinthetropicallowlands.Proc.K.ned Akad.Wet.**40**:530-538.

Hauer, F.R., & A. C. Benke., 1991: Rapid growth of snag dwelling chironomids in a blackwater river: the influence and discharge. Journal of North American Benthological society. **10** (2): 154-164.

Hawkins, C. P & Sedell, J. R., 1981: Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology, **62**:387-397.

Hellawell, J. M., 1986: Biological Indicators of Fresh water Pollution and Environmental Management. Elsevier Applied Science Publishers, London, England.546pp.

Herbert, H. Ross., 1963: Stream communities and terrestrial biomes. Arch.Hydrobiol. **59**: 235-242.

Herrera, 1972: Suelos podzolicos tropicales en regions de rios de agues negras del territorio Amazonas. Characterization quimica y mineralogical de algunos perfiles. Acta cient .venezolana .**23** (Supl.): 31.

Heyligers, P. C., 1963: Vegetation and soil of a white sand savanna in Suriname. N.V. Noord-Hollandsche Uitgevers Maatschappii. Amsterdam. 148pp.

Hughes, R. M., and P. R. Kaufmann, A. T. Kincaid, L. Reynolds and D.P.Larsen.1998. A process for developing and evaluating indices of fish assemblage integrity. Can.J.Fish.Aquatic.Scie.**55**: 1618-1631.

Hughes, L. Duncan, 2006: Development of biological reference conditions of wadeable streams in the major ecoregions and subecoregions of Georgia. Thesis (M.S). Columbus State University.

Hughes, R. M., 1995: Defining acceptable biological status by comparing with reference conditions. Pages 31-47 in W.S.Davis and T.P. Simon (editors). Biological assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers, Ann Arbor, Michigan.

Hynes, H. B. N., 1961: The invertebrate fauna of A Welch mountain stream. Arch.Hydrobiol.**57**:344-88

Hynes, H. B. N., 1970: The Ecology of Running Waters. Liverpool Univ.press.

Hynes, H. B. N., 1975: The stream and its valley. Verh.Int.Ver.Limnol.**19**:1-15.

Hyurn, A. D., and J. B. Wallace., 1987: Local geomorphology as a determinant of macrofaunal production in a mountain stream. Ecology. **68**: 1932-1942.

Jacobi, D. D. I, and Benke, A. C., 1991: Life histories and abundance patterns of snag dwelling mayflies in a coastal plain blackwater river. J.N.Am.Benthol.Soc.**10**:372-387.

Jacobi, D. D. I, and Benke, A. C., 1987: Life histories and abundance patterns of snag dwelling mayflies in a black water coastal plain river. J.N.Am.Benthol.Soc. **10**: 372-387.

Janzen, D. H., 1974: Tropical black water rivers, animals and mast fruiting by the Dipterocarpaceae Biotropica **6**:69-103

Karr, J. R., K. D. Faush., P. L. Angermeier, P. R. Yant, and I. J. Schlosser., 1986: Assessing biological integrity in running waters; a method and its rationale. Special Publication 5. Illinois Natural History Survey, Urbana.

Kaushik, N. K., and H.B. N. Hynes. 1971: The fate of dead leaves that fall into streams. Arch. Hydrobiol. **68** : 465-515.

Kerans, B. L., J. R Karr, and S. A .Ahlstedt. 1992: Aquatic invertebrate assemblages: Spatial and temporal differences among sampling protocols. Journal of the North American Benthological Society. **11**: 377-390.

Kerans, B. L. and J. R. Karr., 1994: A benthic index of biotic integrity (B-BI) from rivers of the Tennessee Valley. Ecological Applications. **4**:768-785.

Klinge, H. 1967. Podzol soils: A source of black water rivers in Amazonia. Atlas de simposia Sobre a Biota Amazonia. Limnologia. **3**: 117-125.

Kolkwitz, R. and M. Marsson., 1908: Ecology of plant saprobia. (Translated 1967).Pages 47-52 in L.E. Keup, W.M. Ingram and K.M. Mac Kenthum (Eds).Biology of water pollution .Federal water pollution control Administration, Washington, DC. Larson, R.A. 1978. Dissolved organic matter of a low colored stream. Freshwater Biol. **8**: 91-104.

Lamar, W. L., 1968: Evaluation of organic color and iron in natural surface waters. U.S .Geol. Surv. Prof. Paper 600-D, D24-D29.

Larson, R. A., 1978: Dissolved organic matter of low colored stream. Fresh water Biology. **8**: 91-104.

Leenheer, J., 1980: Origin and nature of humic substances in the waters of the Amazon River Basin.-Acta Amazonica .**10**: 51-526.

Leonard, A. Smock, Ellen Gilinsky, and Daniel L. Stoneburner., 1985: Macroinvertebrate Production in Southeastern United States Black water. Ecology: Vol. **66**, No. 5, pp. 1491–1503.

Lenat, D. R., 1983: Chironomid taxa richness: Natural variation and use in pollution assessment Freshwat. Invertebr Biol. V. **2**(4):192-198.

Lenat, D. R., 1988: Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. J.N. Am. Benthol. Soc. **7**: 222-233.

Lenat, D. R., 1993: A Biotic index for the southeastern United States: Derivation and list of tolerance values, with criteria for assigning water-quality ratings. Journal of North American Benthological Society .**12**:279-290.

Lyons, J., 1992: Using the index of biotic integrity (IBI) to measure environmental quality in warm water streams of Wisconsin. General Technical Report, NC-149. US Department of Agriculture, Forest Service, St.Paul, Minnesota.

McCune, B., and M. J. Mefford.1997.PC-ORD. Multivariate Analysis of Ecological Data, Version 3.0. MjM Software Design, Gleneden Beach, OR.

Meehan, W. R. Swanson, F. J., and Sedell, J. R., 1977: Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. In Importance, Preservation and management ofRiparianHabitat,pp.137-45.WashingtonDC:USDA For.Serv.Gen.Tech.Rep. R-M 43. 217pp.

Merritt, R. W. and K. W. Cummins., 1996: An Introduction to the Aquatic Insects of North America. 3rd edition. Kendall/Hunt Publishing Co., Dubuque, A.

Meyer J. L., 1986: Dissolved organic carbon dynamics in two subtropical black water rivers. - Arch. Hydrobiol.in press.

Meyer J. L., Edwards R. T, and Risley, R., 1987: Bacterial growth and dissolved organic carbon from a black water river. Microbial Ecology. **13**: 13-29.

Meyer, J. L., 1990. A blackwater perspective on riverine ecosystems. Bioscience **40**:643-651.

Minshall, G. W., 1967: Role of allochthonous detritus in the trophic structure of a woodland spring brook community. Ecology. **48**: 139-149.

Minshall, G. W., 1978: Autotrophy in stream ecosystems. Bioscience. **28**(12). 767-771.

Minshall, G. W., 1981: Structure and temporal variations of the benthic macroinvertebrate community inhabiting Mink Creek, Idaho, U.S.A., a third order Rocky Mountain Stream. Journal Freshwater.Ecol. **1**:13-26.

Minshall, G.W., K. W. Cummins, R. C. Petersen, C.E. Cushing, T.L. Bott, J. R. Sedell, C. E., Cushing, and R. L. Vannote, 1983 : Interbiome comparison of stream ecosystem dynamics.- Ecol. Monogr. **53**: 1-25.

Minshall, G. W., 1984. Aquatic insect-substratum relationships. Pages 358-400 in V. R. Resh and D. M. Rosenburg (editors). The ecology of aquatic insects.Preager Publishers, New York.

Minshall, G.W., K. W. Cummins, R. C. Petersen, C.E. Cushing, D.A. Bruns, J. R. Sedell, C. E., Cushing, and R. L. Vannote, 1985 : Developments in stream ecosystem theory. - Can. J. Fish. Aquat. Sci. **42**: 1045- 1055.

Morse, J. C., J. W. Chapin, D. D. Herlong, and R. S. Harvey., 1984: Aquatic Insects of Upper Three Runs Creek, Savannah River Plant, South Carolina. Part II: Orders other than Diptera. J. George Entomol. Soc. **18**: 303-316.

Naiman, R. J., 1982: Charasteristics of sediment and organic carbon export from pristine boreal forest watersheds. - Can.J.Fish.Aquatic Sci. **39**: 1699-1718.

National Research Council (U.S.)., 1992: Restoration of Aquatic Systems: Science, Technology, and Public Policy. National Academy Press, Washington DC.

Nilson, H. C., and R. W.Larimore.1973: Establishment of invertebrate communities on log substrates in the Kalkaska River, Illinois. Ecology **54**: 366-374.

Ohio EPA (Environmental Protection Agency). 1987: Biological criteria for the protection of aquatic life. Volumes 1-3. Monitoring and Assessment Program, Surface Water Section, Division of Water Quality, Columbus, Ohio.

Olson, J. R. 2002: Using GIS and Land Use Data TO Select Candidate Reference Sites For Stream Bioassessment.p:17-30

Omernik, J. M. 1987: Ecoregions of the conterminous US.Ann.Assoc.Am.Georg. **77**:118-25.

Omernik, J. M. 1995: Ecoregions: A spatial framework for environmental management. Pages 49-62 in W.S.Davis and T.P. Simon (editors). Biological assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers, Bacon Raton, Florida.

Palmer, M. N. 1993: Experimentation in the hyphoreic zone: challenges and prospectus. Journal of North American Benthological society. **12**:84-93.

Paul, R. W., Jr., E. F. Benfield, and J. Cairns, Jr.1978.Effects of thermal discharge on leaf decomposition in a river ecosystem.Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie .**20**: 1759-1766.

Plafkin, J. K., M. T. Barbour, K. D. Porter, S. K. Gross, and R.M. Hughes.1989. Rapid bioassessment protocols for use in streams and rivers. Benthic Macroinvertebrates and Fish. EPA/440/489/001,Office of Water Regulations and Standards, U.S. EPA, Washington, DC.

Pomery, L . R, 1979: Microbial roles in aquatic food webs, p, 85-109. In Aquatic microbial ecology. Proc, Conf. Am.Soc. Mocrobiol. Maryland Sea Grant Publ.

Porter, K. G., and Y. S. Feig. 1980. The use of DAPI for identifying and counting aquatic microflora. Limnol, Oceanogr.**25**: 943-946.

Quality Assurance Project plan (QAPP), 2002. Columbus State University.

Resh, V. H. and Jackson, J. K., 1993: Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. Pp.195-233 in: D. M. Rosenberg and V. H. Resh (eds.), Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York.

Resh, V. H., R. H. Norris, and M. T. Barbour., 1995: Design and implementation of rapid assessment approaches for water resource monitoring using benthic macroinvertebrates. Australian Journal of Ecology 20: 108-121.

Rosenberg, D. M. and Resh, V. H., 1993: Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York. 488pp

Rosenberg, D. M. and Resh, V. H., 1996: Use of aquatic insects in biomonitoring .Pages 87-97 in R.W. Merritt and Cummins (Eds.) An introduction to the Aquatic insects of North America, 3rd ed. Kendall/Hunt, Dubuque, IA.

Schnitzer, M., 1971: Metal –Organic Matter Interactions in Soils and waters. In Organic Compounds in Aquatic Environments. S.D. Faust and J.V.Hunter, (eds.) Marcel Dekker, Inc., New York.

Sedell, J. R., Triska, F. J., Hall, J. D., Anderson, N. H., Lyford, J. H., 1974: Sources and fates of organic inputs in coniferous forest streams. In Integrated Research in the Coniferous Forest Biome, Ecosyst. Anal. Stud., US/IBP,Bull.No.5.ed. R.H.Waring, R.L. Edmonds. Pp. 57-69. Seattle : Univ, Washington.

Sedell. J. R. and J. L. Frogatt., 1984: The importance of stream side forests to large rivers: the isolation of Willamette River, Oregon, USA, from its floodplain. Verh. Int. Verein.Limnolo.**22**:1828-34.

Sioli. H. 1975. Tropical rivers as expressions of their terrestrial environments. Pp.275-288.in: F.B. Golley and E. Medina (eds.) Tropical Ecological Systems: Trends in Terrestrial and Aquatic Research. Springer-Verlag, New York.

Slater. J.V., 1954: The quantitative evaluation of dissolved organic matter in natural waters.Trans Amer.Micros.Soc.**85**: 2497-2507.

Smith. E. P., and J. R. Voshell. Jr., 1997: Studies of Benthic Macroinvertebrates and Fish in streams within EPA Region 3 for Development of Biological Indicators of Ecological Condition. Virginia Polytechnic Institute and State University. Blacksburg. VA.

Smock. L. A., J. E. Gladden. J. L. Riekenberg, L. C. Smith, and C. R. Black., 1992: Lotic macroinvertebrate production in three dimensions: channel surface, hyporheic, and floodplain environments. Ecology .**73**: 876-886.

Smock. L. A., Gilinsky, E., and Stoneburner. D. L. 1985. Macroinvertebrate production in a southeastern black water stream. Ecology. **66**:1494-1503.

Smock. L. A.. and C. E. Roeding.1986: Thetrophic basis of production of the macroinvertebrate community of a southeastern U.S.A. black water stream.Holarct.Ecol.**9**:165-174.

Southerland. M. T. and J. B. Stribling. 1995. Status of biological criteria development and implementation. Pages 81-96 in W.S.Davis and T.Psimon (editors). Biological assessment and criteria: Tools for water resource planning and decision making. Lewis publishers, Boca Raton, Florida.

Stanford. J. A., and A. R. Gaufin., 1974: Hyporheic communities of two Montana Rivers. Science. **185**: 700-702.

Stanford. J. A., and J.V.Ward., 1988: The hyphoreic habitat of river ecosystems. Nature. **335**:64-66.

Stanley, E. H., and A. J. Boulton., 1993: Hydrology and the distribution of hyporheos: Perspectives from a mesic river and a desert stream .Journal of the North American Benthological Society. **12**:9-83.

Stites. D. L., 1986: Secondary production and productivity in the sediments of black waters rivers. - Ph.D. Diss.Emory University. Atlanta, GA. U.S.A.

Stockner. J. G., and K. G. Porter., 1988: Microbial food webs in freshwater planktonic ecosystems. Pages 69-84 in S.R. Carpenter, ed. Complex Interactions in Lake Communities. Springer-Verlag, New York.

St. John T. V, Anderson, A. B., 1982: A reexamination of plant phenolics a source of tropical black water rivers. Trop Ecol. **23**: 151-154.

Stribling, J. B., J. Lathrop-Davis, M. T .Barbour, J.S.White and E.W.Leppo.1995: Evaluation of the environmental indicators for the wetlands of Montana: the multimetric approach using benthic macroinvertebrates. Montana Department of Health and Environmental Science, Helena.

Stribling, J. B., B. K. Jessup and J.Gerritsen. 1999. Development of Biological and Habitat Criteria for Wyoming Streams and Their Use in the TMDL Process. Prepared by Tetra Tech, Inc., Owins Mills, MD, for U.S.EPA, Region 8, Denver, CO.

Suberkrop. K., G. L. Godshalk, and M. J. Klug: 1976.Changes in the chemical composition of the leaves during processing in a woodland stream .Ecology. **57**:720-727.

TetraTech.. 2001.

Vannote. R. L., Minshall. G. W., Cummins. K.W., Sedell. J. R., and Cushing. C. E., 1980: The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences .**37**:130-137.

Vincent & John., 1975: Water quality monitoring and aquatic organisms: the importance of species identification .Journal WPCF. Vol.**47**:9-19.

Wallace. J. B., and Benke A. C., 1984: Quantification of wood habitat in subtropical coastal plain streams. Canadian Journal of Fisheries and Aquatic Sciences, 441. 1643-1652.

Wallace. J. B., Gurtz . M. E., 1986:Response of Baetis mayflies (Ephemeroptera) to catchment logging.American Midland Naturalist. **115**: 25-41.

Wallace, J. B., J. Webster, and W. R. Woodall., 1977: The role of filter feeders in flowing waters. Archiv fur Hydrobiologie. **79**:502-532.

Wallace, J. B., Benke, A. C., Lingle, A. H. & Parsons, K., 1987: Trophic pathways of macroinvertebrate primary consumers in subtropical blackwater streams. Arch.Hydrobiol./Suppl. **74**: 423-451.

Wallace, J. B., J. W. G. Grubough, and M. R. Whites., 1996: Biotic indices and stream ecosystem process results from an experimental study .Ecological applications.**6**:140-141.

Whittier, T. R., R. R. M. Hughes and D. P. Larsen.1988: Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Can.J.Fish.Aquat.Sci. **45**: 1264-1278

Williams, D. D., 1984: The hyporheic zone as a habitat for aquatic insects and associated arthropods. Pages 430-455 in V.H.Resh and D.R.Rosenberg (Eds.) The Ecology of Aquatic Insects.Praeger, New, New York, NY.

Chemistry Data -Appendix A								
StationID	**Alkalinity**	**Conductivity**	**Hardness**	**Iron**	**pH**	**Turbidity**	**Total Phosphorus**	**Copper**
65c-80	8.22	0.0489	17.99	<0.1	6.16	3	<0.01	<0.1
65c-89	0.99	0.0129	4.26	0.156	5.29	6.9	<0.01	<0.1
65d-14	8.62	0.0437	20.84	0.917	6.35	39.6	<0.01	<0.1
65d-18	13.27	0.0577	23.03	<0.1	6.76	9.6	<0.01	<0.1
65d-3	0.0	0.0517	8.97	<0.1	4.13	0	<0.01	<0.1
65d-38	13.39	0.0466	18.08	<0.1	6.48	8.8	<0.01	<0.1
65d-4	0.0	0.042	6.09	<0.1	4.1	0	<0.01	<0.1
65g-120	17.36	0.0524	23.03	<0.1	6.75	13.8	<0.01	<0.1
65g-62	175.99	0.4	196.91	<0.1	7.35	3.4	<0.01	<0.1
65g-82	127.01	0.343	150.93	<0.1	6.83	5	<0.01	<0.1
65h-202	6.17	0.0341	8.38	<0.1	6.09	9.6	<0.01	<0.1
65h-203	52.73	0.1414	57.71	<0.1	7.51	10.2	<0.01	<0.1
65h-206	26.41	0.0826	31.31	<0.1	6.83	10.9	<0.01	<0.1
65h-212	25.76	0.0759	32.59	0.567	6.96	10.7	<0.01	<0.1
65k-54	22.57	0.1118	53.08	<0.1	6.63	4.2	<0.01	<0.1
65k-55	36.70	0.0958	47.15	<0.1	6.9	5.3	<0.01	<0.1
65k-56	23.44	0.1074	48.78	<0.1	6.26	9	<0.01	<0.1
65k-68	144.06	0.433	165.71	<0.1	6.97	14.4	<0.01	<0.1
65k-85	38.35	0.427	179.28	<0.1	6.51	2.5	<0.01	<0.1
65l-10	50.59	0.1345	51.26	0.863	6.92	4.7	<0.01	<0.1
65l-342	1.64	0.054	13.86	5.487	5.31	2.8	<0.01	<0.1
65l-343	3.69	0.0724	16.58	<0.1	5.71	0.3	<0.01	<0.1
65o-12	33.79	0.1092	45.72	<0.1	6.49	10.5	<0.01	<0.1
65o-23	7.13	0.0598	11.63	0.248	5.88	0	<0.01	<0.1
65o-25	0.372	0.0449	6.36	<0.1	4.97	9.5	0.018	<0.1
HH24	0.0	0.003	5.52	0.140	5.08	0.4	0.016	<0.1
HH25	0.0	0.0193	10.34	12.99	4.34	0	0.209	<0.1
HH26	0.0	0.0151	10.82	<0.1	4.5	1.1	0.054	<0.1
HH29	13.36	0.0555	22.22	<0.1	6.55	15.6	0.050	<0.1
75e-59	0.0	0.069	11.04	<0.1	3.91	12.8	0.042	<0.1
75e-60	0.0	0.0554	7.69	<0.1	4.09	4.7	<0.01	<0.1
75e-78	0.0	0.0615	17.80	0.257	4	3.1	<0.01	<0.1
75f-126	20.89	0.12	40.13	<0.1	6	3.4	<0.01	<0.1
75h-10	0.0	0.0731	11.69	1.153	4.42	5.2	<0.01	<0.1
75h-35	0.0	0.633	13.91	0.195	4.44	1.2	<0.01	<0.1
75h-60	7.47	0.0669	15.38	1.366	5.45	8.1	<0.01	<0.1
75h-66	2.17	0.0613	12.91	1.600	5.47	3.1	<0.01	<0.1
75j-31	8.56	0.1202	25.83	<0.1	5.72	3	<0.01	<0.1

Appendix B

Southern coastal plain streams - Metrics with Discrimination Efficiency of 50% and Above

StationID	Condition	R & I	AmphPct	NonInPct	OdonPct	OligoPct	%Tpod/TC
75e-20	BW_Imp	I	3.75	13.33	1.25	9.58	0.00
75e-36	BW_Imp	I	0.90	72.52	0.90	15.77	8.57
75e-46	BW_Imp	I	0.00	71.11	1.78	6.67	43.64
75e-54	BW_Imp	I	4.17	19.58	4.17	0.83	22.22
75f-137	BW_Imp	i	4.17	72.50	1.25	0.00	17.78
75f-44	CW_Imp	i	0.00	22.00	1.00	5.00	3.28
75f-45	CW_Imp	i	0.00	82.73	0.91	41.82	42.86
75f-50	CW_Imp	i	0.00	81.86	1.77	24.78	55.56
75h-1	BW_Imp	i	19.17	63.33	0.00	6.67	0.00
75h-70	BW_Imp	i	0.44	40.44	4.00	0.00	12.99
75j-13	CW_Imp	i	4.64	6.75	0.00	1.27	1.74
75j-2	CW_Imp	i	0.00	9.29	0.44	4.87	28.45
75j-4	CW_Imp	i	0.00	2.92	0.00	2.92	98.51
75e-23	BW_Ref	r	1.04	8.85	0.00	1.04	0.00
75e-59	BW_Ref	r	4.33	13.85	0.43	0.87	2.47
75e-60	BW_Ref	r	2.50	15.42	0.83	0.83	17.71
75e-69	BW_Ref	r	1.66	6.08	0.00	0.00	1.21
75e-78	BW_Ref	r	2.50	17.92	0.00	0.42	0.00
75f-126	CW_Ref	r	8.07	21.08	0.00	8.07	0.00
75f-91	BW_Ref	r	0.00	0.47	0.00	0.00	0.47
75h-10	BW_Ref	r	2.74	10.96	0.00	4.11	0.00
75h-35	BW_Ref	r	0.00	1.69	0.00	1.27	0.00
75h-45	BW_Ref	r	2.96	2.96	0.00	0.00	0.00
75h-60	BW_Ref	r	11.67	29.58	2.92	4.17	0.00
75h-66	BW_Ref	r	0.42	6.25	9.17	0.83	34.38
75j-10	BW_Ref	r	4.93	11.33	0.00	0.99	0.59
75j-15	BW_Ref	r	0.42	34.17	0.42	1.67	1.34
75j-25	BW_Ref	r	30.42	45.00	0.42	5.83	1.64
75j-29	BW_Ref	r	5.00	98.75	0.42	0.42	0.00
		min	0.00	0.47	0.00	0.00	0.00
		5	0.00	1.39	0.00	0.00	0.00
		25	0.8854167	6.206837	0	0.4166667	0
		75	4.9445813	23.203008	0.4207251	2.2773973	1.4165475
		95	16.354167	58.4375	4.4791667	6.3929372	21.875
		max	30.416667	98.75	9.1666667	41.818182	98.514851
			7	7	10	9	11
			13	13	13	13	13
		DE	**53.846154**	**53.846154**	**76.923077**	**69.230769**	**84.615385**

Appendix C									
Southern coastal plain ecoregion (75) - Standardized Metrics and Final Index									
StationID	**Condition**	**I & R**	**NonInPct**	**OdonPct**	**OligoPct**	**%Tpod/TC**	**BrrwrPct**	**AmphPct**	**Index**
75e-20	BW_Imp	I	88	86	77	100	13	23	75
75e-36	BW_Imp	I	27	90	62	91	10	6	55
75e-46	BW_Imp	I	28	81	84	56	39	0	50
75e-54	BW_Imp	I	81	55	98	77	25	25	67
75f-137	BW_Imp	i	27	86	100	82	3	25	64
75f-44	CW_Imp	i	79	89	88	97	74	0	71
75f-45	CW_Imp	i	16	90	0	56	6	0	33
75f-50	CW_Imp	i	17	81	41	44	37	0	36
75h-1	BW_Imp	i	36	100	84	100	56	100	84
75h-70	BW_Imp	i	60	56	100	87	30	3	61
75j-13	CW_Imp	i	94	100	97	98	27	28	84
75j-2	CW_Imp	i	92	95	88	71	100	0	69
75j-4	CW_Imp	i	98	100	93	0	35	0	58
75e-23	BW_Ref	r	92	100	98	100	0	6	79
75e-59	BW_Ref	r	87	95	98	97	32	26	81
75e-60	BW_Ref	r	86	91	98	82	100	15	74
75e-69	BW_Ref	r	95	100	100	99	97	10	81
75e-78	BW_Ref	r	83	100	99	100	76	15	79
75f-126	CW_Ref	r	80	100	81	100	100	49	82
75f-91	BW_Ref	r	100	100	100	100	23	0	80
75h-10	BW_Ref	r	90	100	90	100	3	17	79
75h-35	BW_Ref	r	100	100	97	100	55	0	79
75h-45	BW_Ref	r	98	100	100	100	55	18	83
75h-60	BW_Ref	r	71	68	90	100	63	71	80
75h-66	BW_Ref	r	95	0	98	65	84	3	52
75j-10	BW_Ref	r	90	100	98	99	38	30	83
75j-15	BW_Ref	r	66	95	96	99	70	3	72
75j-25	BW_Ref	r	55	95	86	98	40	100	87
75j-29	BW_Ref	r	0	95	99	100	0	31	65
								25th	**78**
									12
									16
								DE	**75**

Appendix D						
Southern coastal plain black water streams (Ecoregion 75) – Metrics with Discrimination Efficiency 50% and Above						
StationID	**Condition**	**IsoPct**	**NonInPct**	**OdonPct**	**OligoPct**	**%Tpod/TC**
75e-20	BW_Imp	0.00	13.33	1.25	9.58	0.00
75e-36	BW_Imp	54.95	72.52	0.90	15.77	8.57
75e-46	BW_Imp	0.89	71.11	1.78	6.67	43.64
75e-54	BW_Imp	13.33	19.58	4.17	0.83	22.22
75f-137	BW_Imp	68.33	72.50	1.25	0.00	17.78
75h-1	BW_Imp	2.50	63.33	0.00	6.67	0.00
75h-70	BW_Imp	40.00	40.44	4.00	0.00	12.99
75e-23	BW_Ref	6.77	8.85	0.00	1.04	0.00
75e-59	BW_Ref	8.66	13.85	0.43	0.87	2.47
75e-60	BW_Ref	12.08	15.42	0.83	0.83	17.71
75e-69	BW_Ref	4.42	6.08	0.00	0.00	1.21
75e-78	BW_Ref	15.00	17.92	0.00	0.42	0.00
75f-91	BW_Ref	0.47	0.47	0.00	0.00	0.47
75h-10	BW_Ref	3.65	10.96	0.00	4.11	0.00
75h-35	BW_Ref	0.00	1.69	0.00	1.27	0.00
75h-45	BW_Ref	0.00	2.96	0.00	0.00	0.00
75h-60	BW_Ref	7.50	29.58	2.92	4.17	0.00
75h-66	BW_Ref	0.83	6.25	9.17	0.83	34.38
75j-10	BW_Ref	5.42	11.33	0.00	0.99	0.59
75j-15	BW_Ref	31.25	34.17	0.42	1.67	1.34
75j-25	BW_Ref	3.75	45.00	0.42	5.83	1.64
75j-29	BW_Ref	10.83	98.75	0.42	0.42	0.00
	Min	0	0	0	0	0
	5th	0	1.3272857	0	0	0
	25th	2.2431507	6.163674	0	0.4166667	0
	50th	5.4187192	11.330049	0	0.8658009	0.4716981
	75th	9.745671	23.75	0.4247835	1.4689266	1.4908131
	95th	19.875	61.125	4.7916667	4.6666667	22.708333
	Max	68.333333	98.75	9.1666667	15.765766	43.636364
		4	5	5	4	5
		7	7	7	7	7
	DE	**0.5714286**	**0.7142857**	**0.7142857**	**0.5714286**	**0.7142857**

Appendix E							
Southern coastal plain Black water streams (Ecoregion75) -Standardized Metrics and Final Index							
StationID	**Condition**	**IsoPct**	**NonInPct**	**OdonPct**	**OligoPct**	**%Tpod/TC**	**Index**
75e-20	BW_Imp	100	88	86	39	100	83
75e-36	BW_Imp	20	27	90	0	80	43
75e-46	BW_Imp	99	28	81	58	0	53
75e-54	BW_Imp	80	81	55	95	49	72
75f-137	BW_Imp	0	27	86	100	59	55
75h-1	BW_Imp	96	36	100	58	100	78
75h-70	BW_Imp	41	60	56	100	70	66
75e-23	BW_Ref	87	99	100	100	94	96
75e-59	BW_Ref	82	86	91	95	59	83
75e-60	BW_Ref	94	95	100	100	97	97
75e-69	BW_Ref	78	83	100	97	100	92
75e-78	BW_Ref	99	100	100	100	99	100
75f-91	BW_Ref	95	90	100	74	100	92
75h-10	BW_Ref	100	100	100	92	100	98
75h-35	BW_Ref	100	98	100	100	100	100
75h-45	BW_Ref	89	71	68	74	100	80
75h-60	BW_Ref	99	95	0	95	21	62
75h-66	BW_Ref	92	90	100	94	99	95
75j-10	BW_Ref	54	66	95	89	97	80
75j-15	BW_Ref	95	55	95	63	96	81
75j-25	BW_Ref	84	0	95	97	100	75
75j-29	BW_Ref	90	92	100	93	64	88
						25th	**81**
							11
							15
						DE	**73**

Appendix F				
Southern coastal plain Clear water streams (Ecoregion 75)- Metrics with Discrimination efficiency of 50% and Above				
StationID	**Cond**	**Amph%**	**NonIn%**	**%Tpod/TC**
75f-44	CW_Imp	0.00	22.00	3.28
75f-45	CW_Imp	0.00	82.73	42.86
75f-50	CW_Imp	0.00	81.86	55.56
75j-13	CW_Imp	4.64	6.75	1.74
75j-2	CW_Imp	0.00	9.29	28.45
75j-4	CW_Imp	0.00	2.92	98.51
75f-126	CW_Ref	8.07	21.08	0.00
	0	8.0717489	21.076233	0
	5th	8.0717489	21.076233	0
	25th	8.0717489	21.076233	0
	50th	8.0717489	21.076233	0
	75th	8.0717489	21.076233	0
	95th	8.0717489	21.076233	0
	100	8.0717489	82.727273	98.514851
		5	3	6
		6	6	6
	DE	**83.333333**	**50**	**100**

Appendix F- Continued (1)					
Southern coastal plain Clear water streams (Ecoregion 75)- Metrics with Discrimination efficiency of 50% and Above					
StationID	**Cond**	**CrCh2Chi%**	**NCBI**	**CletTax**	**PrdTax**
75f-44	CW_Imp	5.63	9.71	9	4
75f-45	CW_Imp	16.67	7.20	4	2
75f-50	CW_Imp	0.00	8.07	4	6
75j-13	CW_Imp	1.74	7.47	19	5
75j-2	CW_Imp	17.24	8.67	14	8
75j-4	CW_Imp	1.49	9.80	5	2
75f-126	CW_Ref	0.00	8.16	6	6
	0	0	8.16	6	6
	5th	0	8.16	6	6
	25th	0	8.16	6	6
	50th	0	8.16	6	6
	75th	0	8.16	6	6
	95th	0	8.16	6	6
	100	17.241379	9.8000002	19	8
		3	3	3	4
		6	6	6	6
	DE	**50**	**50**	**50**	**66.666667**

Appendix G				
Southern coastal plain clear water streams (Ecoregion 75)- Standardized Metrics and Final Index				
StationID	**Condition**	**NonInPct**	**%Tpod/TC**	**CrCh2ChiPct**
75f-44	CW_Imp	99	97	67
75f-45	CW_Imp	0	56	3
75f-50	CW_Imp	1	44	100
75j-13	CW_Imp	100	98	90
75j-2	CW_Imp	100	71	0
75j-4	CW_Imp	100	0	91
75f-126	CW_Ref	100	100	100

Appendix G- Continued..					
Southern coastal plain clear water streams (Ecoregion 75)- Standardized Metrics and Final Index					
StationID	**Condition**	**CllctTax**	**PredTax**	**Amph%**	**Index**
75f-44	CW_Imp	100	67	0	72
75f-45	CW_Imp	67	33	0	43
75f-50	CW_Imp	67	100	0	69
75j-13	CW_Imp	100	83	58	95
75j-2	CW_Imp	100	100	0	73
75j-4	CW_Imp	83	33	0	51
75f-126	CW_Ref	100	100	100	100
				25th	**100**
					0
				DE	**1**

16	sites	Appendix H			
9	variable	Revitalized metrics- Ecoregion 75			
	Q	Q	Q	Q	Q
	AmphPct	IsoPct	NonInPct	OdonPct	OligoPct
75e-23	0.029733	0.162689	0.071283	0	0.087302
75e-59	0.123567	0.208034	0.111526	0.044665	0.072563
75e-60	0.07136	0.290338	0.124116	0.08598	0.069842
75e-69	0.04731	0.106201	0.048927	0	0
75e-78	0.07136	0.360419	0.144243	0	0.034921
75f-126	0.230399	0.086199	0.16968	0	0.676495
75f-91	0	0.011281	0.00378	0	0
75h-10	0.078202	0.087773	0.088228	0	0.344426
75h-35	0	0	0.013645	0	0.106538
75h-45	0.084366	0	0.023795	0	0
75h-60	0.333012	0.18021	0.238168	0.300931	0.349209
75h-66	0.011893	0.020023	0.050317	0.945784	0.069842
75j-10	0.14061	0.130201	0.091216	0	0.082572
75j-15	0.011893	0.750873	0.275068	0.04299	0.139684
75j-25	0.868209	0.090105	0.362284	0.04299	0.488893
75j-29	0.142719	0.260303	0.795013	0.04299	0.034921

Appendix I								
Southeastern plain streams (Ecoregion 65)- Metrics with a DE of 50%and Above								
StationID	**r&i**	**EpTax**	**EPT%**	**Ep%**	**Cole%**	**Olgo%**	**Trh%**	**Tny2Ch%**
65c-40	i	5	17.92	5.00	6.67	0.00	9.58	7.24
65l-420	i	1	0.42	0.42	1.67	0.42	0.00	12.43
65l-423	i	1	0.42	0.42	5.83	26.25	0.00	15.28
65o-22	i	0	0.00	0.00	2.31	18.51	0.00	6.67
65c-12	i	5	46.67	39.58	3.33	0.00	5.00	41.11
65c-3	i	2	39.55	31.64	2.26	1.69	7.91	1.15
65c-4	i	0	0.00	0.00	1.32	3.52	0.00	14.86
65c-5	i	0	4.26	0.00	10.64	4.68	4.26	34.38
65c-8	i	2	25.78	1.78	4.00	0.00	24.00	10.59
65c-88	i	5	14.75	9.22	0.92	0.46	2.30	11.19
65d-1	i	0	0.42	0.00	0.00	11.67	0.42	2.13
65d-20	i	0	21.46	0.00	3.41	0.00	7.32	8.80
65d-21	i	4	22.92	15.83	5.83	0.42	1.25	6.45
65d-32	i	3	17.80	13.98	0.00	0.00	2.97	23.35
65d-39	i	3	28.75	5.00	5.83	0.42	10.83	15.32
65g-10	i	0	0.00	0.00	3.33	17.50	0.00	1.53
65g-130	i	0	1.38	0.00	2.76	10.14	1.38	37.27
65g-135	i	1	9.62	9.62	0.00	5.29	0.00	1.18
65g-137	i	0	0.00	0.00	1.36	8.18	0.00	0.69
65g-14	i	1	1.45	1.45	0.48	19.32	0.00	3.79
65g-17	i	1	1.69	0.84	6.75	12.66	0.84	0.00
65g-4	i	1	9.74	9.74	0.00	20.13	0.00	8.00
65g-69	i	2	4.58	4.58	5.83	5.00	0.00	1.90
65g-8	i	0	0.00	0.00	0.00	9.66	0.00	1.06
65g-84	i	0	0.00	0.00	0.00	24.44	0.00	0.00
65h-17	i	0	7.08	0.00	4.17	5.42	2.08	0.00
65h-174	i	2	20.00	6.25	0.42	1.25	13.33	5.13
65h-32	i	0	0.00	0.00	0.00	11.39	0.00	6.67
65h-34	i	0	0.42	0.00	0.42	3.75	0.42	1.32
65h-41	i	1	9.90	2.60	6.77	2.60	2.08	1.32
65k-102	i	4	17.27	9.09	10.45	0.45	8.18	18.80
65k-113	i	1	0.92	0.46	1.83	0.46	0.46	17.54
65k-128	i	1	7.59	1.79	25.45	0.45	5.80	4.80
65k-129	i	2	5.00	4.58	0.83	8.75	0.00	30.00
65k-37	i	0	5.39	0.00	7.35	0.49	2.45	0.00
65L-184	i	0	2.08	0.00	9.58	3.33	2.08	41.18
65l-391	i	0	0.42	0.00	1.25	4.17	0.42	5.10
65o-11	i	2	4.52	1.36	3.62	8.60	3.17	10.71
65o-18	i	0	1.33	0.00	0.89	18.58	1.33	0.00
65c-89	r	1	8.72	1.54	3.08	1.54	5.13	3.38

Appendix I- Continued (1)						
Southeastern plain streams (Ecoregion 65)- Metrics with a DE of 50%and Above						
StationID	**r&i**	**Tol%**	**Prd%**	**PrdTax**	**CgrTax**	**Cgr%**
65c-40	i	0.42	41.67	23	22	22.92
65l-420	i	10.00	5.42	9	2	10.42
65l-423	i	17.92	7.50	6	1	5.83
65o-22	i	1.39	4.17	6	4	43.06
65c-12	i	0.42	20.00	20	12	22.92
65c-3	i	1.13	4.52	4	11	46.33
65c-4	i	14.98	32.16	13	5	3.52
65c-5	i	2.98	11.49	15	9	11.91
65c-8	i	0.00	11.11	8	12	57.78
65c-88	i	0.92	17.05	15	10	11.06
65d-1	i	2.92	21.67	8	3	2.08
65d-20	i	0.49	18.54	12	7	11.22
65d-21	i	0.00	7.08	8	10	10.00
65d-32	i	0.00	11.02	12	7	19.92
65d-39	i	0.83	10.00	13	21	38.75
65g-10	i	4.58	6.25	7	4	3.75
65g-130	i	6.45	11.06	8	1	0.46
65g-135	i	0.48	4.81	5	0	0.00
65g-137	i	12.73	3.18	6	0	0.00
65g-14	i	2.90	5.31	6	1	11.59
65g-17	i	1.27	8.02	8	3	39.24
65g-4	i	4.55	3.90	5	1	9.09
65g-69	i	4.58	35.42	14	1	0.83
65g-8	i	1.93	1.93	3	0	0.00
65g-84	i	8.89	1.33	3	3	1.33
65h-17	i	4.58	7.08	6	3	3.33
65h-174	i	0.83	24.17	11	11	39.17
65h-32	i	17.30	1.27	1	0	0.00
65h-34	i	3.33	0.00	0	1	0.42
65h-41	i	23.44	15.63	10	3	5.73
65k-102	i	9.55	15.00	15	6	20.00
65k-113	i	3.21	9.17	7	7	4.13
65k-128	i	1.34	10.27	8	5	5.36
65k-129	i	2.08	5.00	6	5	2.50
65k-37	i	0.49	9.31	6	5	10.78
65L-184	i	23.75	11.25	15	2	1.25
65l-391	i	24.17	2.92	4	4	2.92
65o-11	i	14.48	8.14	7	4	9.05
65o-18	i	0.44	7.08	5	3	46.90
65c-89	r	2.05	37.95	14	11	32.31

Appendix I –Continued (2)							
Southeastern plain ecoregion (Ecoregion 65)- Metrics with DE 50% and Above							
StationID	**r&I**	**EpTax**	**Ep%**	**Cole%**	**Oligo%**	**Toler%**	**Pred%**
65o-24	R	4	31.91	0.00	0.00	0.00	3.19
65o-25	R	1	3.41	4.88	4.39	0.98	5.85
65c-80	R	2	2.50	1.25	2.08	2.08	19.58
65d-14	R	6	11.52	5.07	0.00	0.00	23.04
65d-18	R	4	8.33	10.83	0.42	2.50	27.50
65d-3	R	2	10.00	0.42	0.42	7.92	48.75
65d-4	R	0	0.00	0.93	0.47	0.47	13.08
65g-62	R	3	45.83	4.17	2.92	9.17	9.17
HH29	R	8	8.80	11.57	1.39	3.70	15.74
65h-203	R	5	26.67	2.92	0.42	0.83	7.92
65k-54	R	0	0.00	5.85	11.71	0.00	19.02
65k-55	R	6	8.55	17.52	0.00	0.43	19.23
65k-56	R	0	0.00	12.14	0.00	4.05	6.94
65k-68	R	0	0.00	11.34	0.00	45.88	7.73
65k-85	R	0	0.00	0.00	10.05	0.00	1.51
65l-381	R	3	2.53	4.22	1.69	0.42	6.33
65o-12	R	1	0.45	18.10	0.00	6.33	24.43
	min	0	0	0	0	0	0
	5th	0	0	0	0	0	2.1906
	25th	0.5	0.226244	2.38095	0.208333	0.4246	7.3342
	50th	2	2.531646	4.87805	1.507538	1.3158	13.242
	75th	2.5	8.440171	10.4418	3.320035	4.1065	19.407
	95th	6	29.29078	21.6126	10.4849	10.833	38.598
	max	8	45.83333	36.4055	26.25	45.876	48.75
		17	17	20	23	16	17
		31	31	31	31	31	31
	DE	**54.83871**	**54.83871**	**64.5161**	**74.19355**	**51.613**	**54.839**

Appendix I –Continued (3)

Southeastern plain ecoregion (Ecoregion 65)- Metrics with DE 50% and Above

StationID	r&I	PredTax	ClgrTax	Clgr %	Tyt2Chi%
65o-24	R	4	4	31.38	13.21
65o-25	R	4	2	31.22	0.00
65c-80	R	14	12	20.42	11.36
65d-14	R	8	10	30.41	10.20
65d-18	R	19	11	10.42	8.59
65d-3	R	22	3	2.92	1.90
65d-4	R	11	5	13.08	45.21
65g-62	R	9	6	5.42	10.00
HH29	R	6	8	16.20	26.44
65h-203	R	8	6	9.17	56.79
65k-54	R	4	2	23.90	0.00
65k-55	R	11	10	27.35	18.10
65k-56	R	8	3	28.32	0.00
65k-68	R	7	2	2.06	0.00
65k-85	R	3	0	0.00	0.00
65l-381	R	8	8	19.83	50.00
65o-12	R	10	5	3.17	15.00
	min	0	0	0	0
	5th	3	0.5	1.03093	0
	25th	7	3.5	5.67637	0
	50th	8	6	18.2796	10.28571429
	75th	11.5	10	27.2431	19.31818182
	95th	18	13.5	37.136	47.605
	max	23	22	57.7778	56.79012346
		16	18	17	24
		31	31	31	31
	DE	**51.613**	**58.065**	**54.8387**	**77.41935484**

Appendix J						
Southeastern plain streams (Ecoregion 65) – Standardized Metrics and Final Index						
StationID	**r&I**	**Oligo%**	**Toler%**	**Pred%**	**PredTax**	**ClgrTax**
65c-40	I	100	99	100	100	100
65l-420	I	98	78	14	50	15
65l-423	I	0	61	19	33	7
65o-22	I	29	97	11	33	30
65c-12	I	100	99	52	100	89
65c-3	I	94	98	12	22	81
65c-4	I	87	67	83	72	37
65c-5	I	82	94	30	83	67
65c-8	I	100	100	29	44	89
65c-88	I	98	98	44	83	74
65d-1	I	56	94	56	44	22
65d-20	I	100	99	48	67	52
65d-21	I	98	100	18	44	74
65d-32	I	100	100	29	67	52
65d-39	I	98	98	26	72	100
65g-10	I	33	90	16	39	30
65g-130	I	61	86	29	44	7
65g-135	I	80	99	12	28	0
65g-137	I	69	72	8	33	0
65g-14	I	26	94	14	33	7
65g-17	I	52	97	21	44	22
65g-4	I	23	90	10	28	7
65g-69	I	81	90	92	78	7
65g-8	I	63	96	5	17	0
65g-84	I	7	81	3	17	22
65h-17	I	79	90	18	33	22
65h-174	I	95	98	63	61	81
65h-32	I	57	62	3	6	0
65h-34	I	86	93	0	0	7
65h-41	I	90	49	40	56	22
65k-102	I	98	79	39	83	44
65k-113	I	98	93	24	39	52
65k-128	I	98	97	27	44	37
65k-129	I	67	95	13	33	37
65k-37	I	98	99	24	33	37
65L-184	I	87	48	29	83	15
65l-391	I	84	47	8	22	30
65o-11	I	67	68	21	39	30
65o-18	I	29	99	18	28	22
65c-89	r	94	96	98	78	81
HH24	r	95	99	49	72	100

Appendix J- Continued (1)						
Southeastern plain streams (Ecoregion 65) – Standardized Metrics and Final Index						
StationID	**r&I**	**Clgr%**	**EphTax**	**Eph%**	**Coleo%**	**Index**
65c-40	I	62	83	17	31	79
65l-420	I	28	17	1	8	47
65l-423	I	16	17	1	27	26
65o-22	I	100	0	0	11	45
65c-12	I	62	83	100	15	77
65c-3	I	100	33	100	10	60
65c-4	I	9	0	0	6	40
65c-5	I	32	0	0	49	57
65c-8	I	100	33	6	19	66
65c-88	I	30	83	31	4	66
65d-1	I	6	0	0	0	33
65d-20	I	30	0	0	16	52
65d-21	I	27	67	54	27	61
65d-32	I	54	50	48	0	62
65d-39	I	100	50	17	27	74
65g-10	I	10	0	0	15	31
65g-130	I	1	0	0	13	34
65g-135	I	0	17	33	0	37
65g-137	I	0	0	0	6	30
65g-14	I	31	17	5	2	34
65g-17	I	100	17	3	31	57
65g-4	I	24	17	33	0	30
65g-69	I	2	33	16	27	52
65g-8	I	0	0	0	0	29
65g-84	I	4	0	0	0	18
65h-17	I	9	0	0	19	38
65h-174	I	100	33	21	2	65
65h-32	I	0	0	0	0	21
65h-34	I	1	0	0	2	30
65h-41	I	15	17	9	31	43
65k-102	I	54	67	31	48	72
65k-113	I	11	17	2	8	44
65k-128	I	14	17	6	100	62
65k-129	I	7	33	16	4	40
65k-37	I	29	0	0	34	49
65L-184	I	3	0	0	44	44
65l-391	I	8	0	0	6	28
65o-11	I	24	33	5	17	42
65o-18	I	100	0	0	4	43
65c-89	r	87	17	5	14	64
HH24	r	100	33	5	12	69

Appendix J- Continued (2)						
Southeastern plain streams (Ecoregion 65)— Standardized Metrics and Final Index						
StationID	**r&I**	**Oligo%**	**Tol%**	**Prd%**	**PrdTax**	**ClgrTax**
HH25	r	100	98	27	44	100
HH26	r	90	100	100	94	74
65g-82	r	84	73	0	0	0
65g-83	r	94	90	36	50	52
65h-202	r	100	91	36	72	74
65h-206	r	93	100	64	39	30
65h-209	r	83	99	34	56	52
65l-10	r	77	97	23	61	89
65l-342	r	89	95	9	39	30
65l-343	r	98	91	26	44	37
65l-379	r	58	86	7	17	7
65o-23	r	86	99	43	67	89
65o-24	r	100	100	8	22	30
65o-25	r	83	98	15	22	15
65c-80	r	92	95	51	78	89
65d-14	r	100	100	60	44	74
65d-18	r	98	95	71	100	81
65d-3	r	98	83	100	100	22
65d-4	r	98	99	34	61	37
65g-62	r	89	80	24	50	44
HH29	r	95	92	41	33	59
65h-203	r	98	98	21	44	44
65k-54	r	55	100	49	22	15
65k-55	r	100	99	50	61	74
65k-56	r	100	91	18	44	22
65k-68	r	100	0	20	39	15
65k-85	r	62	100	4	17	0
65l-381	r	94	99	16	44	59
65o-12	r	100	86	63	56	37

Appendix J- Continued (3) Southeastern plain streams (Ecoregion 65)— Standardized Metrics and Final Index						
StationID	**r&I**	**Clgr%**	**EphTax**	**Eph%**	**Cole%**	**Index**
HH25	r	100	17	19	38	66
HH26	r	49	17	6	37	65
65g-82	r	0	0	0	0	26
65g-83	r	73	33	3	100	73
65h-202	r	65	33	41	47	68
65h-206	r	35	33	14	100	67
65h-209	r	16	17	3	6	46
65l-10	r	52	33	9	45	61
65l-342	r	24	0	0	10	43
65l-343	r	9	17	21	15	46
65l-379	r	9	0	0	16	31
65o-23	r	63	33	23	40	65
65o-24	r	85	67	100	0	62
65o-25	r	84	17	12	23	54
65c-80	r	55	33	9	6	60
65d-14	r	82	100	100	23	75
65d-18	r	28	67	28	50	73
65d-3	r	8	33	34	2	54
65d-4	r	35	0	0	4	50
65g-62	r	15	50	100	19	50
HH29	r	44	100	30	54	70
65h-203	r	25	83	91	13	60
65k-54	r	64	0	0	27	45
65k-55	r	74	100	29	81	86
65k-56	r	76	0	0	56	61
65k-68	r	6	0	0	52	33
65k-85	r	0	0	0	0	30
65l-381	r	53	50	9	20	60
65o-12	r	9	17	2	84	58
					25th	**48**
						23
						31
					DE	74

Appendix K						
Southeastern plain black water streams (Ecoregion 65) with a DE of 50% and Above						
StationID	**Cond**	**EPTTax**	**TrhTax**	**Evenness**	**PrdTax**	**ClgrTax**
65c-40	BW_1	20	8	0.622	23	22
65l-420	BW_1	1	0	0.546	9	2
65l-423	BW_1	1	0	0.494	6	1
65o-22	BW_1	0	0	0.452	6	4
65c-89	BW_R	6	3	0.539	14	11
HH24	BW_R	11	7	0.603	13	15
HH25	BW_R	12	7	0.571	8	17
HH26	BW_R	7	5	0.603	17	10
65g-82	BW_R	0	0	0.193	0	0
65g-83	BW_R	5	3	0.638	9	7
65h-202	BW_R	6	2	0.568	13	10
65h-206	BW_R	2	0	0.529	7	4
65h-209	BW_R	2	1	0.632	10	7
65l-10	BW_R	7	4	0.554	11	12
65l-342	BW_R	3	3	0.424	7	4
65l-343	BW_R	5	4	0.546	8	5
65l-379	BW_R	0	0	0.513	3	1
65o-23	BW_R	7	3	0.620	12	12
65o-24	BW_R	5	1	0.465	4	4
65o-25	BW_R	3	2	0.449	4	2
	min	0	0	0	0	0
	5th	0	0	0.3663024	2.25	0.75
	25th	2.75	1	0.5005908	6.25	4
	75th	7	4	0.6026783	12.25	11.25
	95th	11.25	7	0.6331588	14.75	15.5
		20	8	0.6380531	23	22
		3	3	2	2	2
	D.E.	**0.75**	**0.75**	**0.5**	**0.5**	**0.5**

Appendix K- Continued (1)				
Southeastern plain black water streams (Ecoregion 65) with a DE of 50% and Above				
StationID	**Cond**	**Dip%**	**CrCh2Chi%**	**Tol%**
65c-40	BW_1	69.58	0.00	0.42
65l-420	BW_1	81.67	1.18	10.00
65l-423	BW_1	41.67	0.00	17.92
65o-22	BW_1	77.78	1.67	1.39
65c-89	BW_R	78.46	0.00	2.05
HH24	BW_R	64.73	0.00	0.45
HH25	BW_R	52.75	0.00	1.10
HH26	BW_R	70.43	0.00	0.00
65g-82	BW_R	0.00	0.00	12.50
65g-83	BW_R	38.69	7.35	4.52
65h-202	BW_R	70.85	0.00	4.02
65h-206	BW_R	27.19	0.00	0.00
65h-209	BW_R	79.91	1.71	0.46
65l-10	BW_R	27.63	0.00	1.32
65l-342	BW_R	84.17	1.10	2.50
65l-343	BW_R	39.58	1.10	4.17
65l-379	BW_R	39.66	0.00	6.32
65o-23	BW_R	72.92	0.00	0.42
65o-24	BW_R	56.91	0.00	0.00
65o-25	BW_R	73.66	1.18	0.98
	min	0	0	0
	5th	20.391705	0	0
	25th	39.360867	0	0.4389881
	75th	73.102134	1.1004189	4.056742
	95th	80.973174	3.1239496	7.8663793
		84.166667	7.3529412	17.916667
		2	2	2
	D.E.	**0.5**	**0.5**	**0.5**

Appendix K- Continued (2)					
Southeastern plain black water streams (Ecoregion 65) with a DE of 50% and Above					
StationID	**Cond**	**Dom01%**	**Oligo%**	**TolrTax**	**Dom01Ind**
65c-40	BW_1	31.25	0.00	1	75
65l-420	BW_1	18.75	0.42	3	45
65l-423	BW_1	26.25	26.25	3	63
65o-22	BW_1	36.11	18.51	3	78
65c-89	BW_R	24.10	1.54	1	47
HH24	BW_R	12.95	1.34	1	29
HH25	BW_R	18.68	0.00	1	34
HH26	BW_R	20.97	2.69	0	39
65g-82	BW_R	67.08	4.17	2	161
65g-83	BW_R	16.58	1.51	4	33
65h-202	BW_R	29.65	0.00	3	59
65h-206	BW_R	15.21	1.84	0	33
65h-209	BW_R	11.87	4.57	1	26
65l-10	BW_R	24.56	6.14	2	56
65l-342	BW_R	46.67	2.92	2	112
65l-343	BW_R	23.75	0.42	4	57
65l-379	BW_R	15.52	10.92	3	27
65o-23	BW_R	10.42	3.72	1	25
65o-24	BW_R	28.72	0.00	0	54
65o-25	BW_R	30.73	4.39	2	63
	min	10	0	0	25
	5th	11.508276	0	0	25.75
	25th	15.439774	1.108631	1	32
	75th	28.954613	4.222561	2.25	57.5
	95th	51.770833	7.3351482	4	124.25
		67.083333	26.25	4	161
		2	2	3	3
	D.E.	**0.5**	**0.5**	**0.75**	**0.75**

Appendix K- Continued (3)					
Southeastern plain black water streams (Ecoregion 65) with a DE of 50% and Above					
StationID	**Cond**	**PrdPct**	**Trch%**	**EPT%**	**Eph%**
65c-40	BW_I	41.67	9.58	17.92	5.00
65l-420	BW_I	5.42	0.00	0.42	0.42
65l-423	BW_I	7.50	0.00	0.42	0.42
65o-22	BW_I	4.17	0.00	0.00	0.00
65c-89	BW_R	37.95	5.13	8.72	1.54
HH24	BW_R	18.75	26.34	29.02	1.34
HH25	BW_R	10.44	13.74	33.52	5.49
HH26	BW_R	39.25	4.30	6.99	1.61
65g-82	BW_R	0.00	0.00	0.00	0.00
65g-83	BW_R	14.07	7.54	8.54	1.01
65h-202	BW_R	14.07	2.51	15.58	12.06
65h-206	BW_R	24.88	0.00	4.15	4.15
65h-209	BW_R	13.24	0.46	1.37	0.91
65l-10	BW_R	8.77	4.39	7.46	2.63
65l-342	BW_R	3.33	1.25	1.25	0.00
65l-343	BW_R	10.00	2.50	8.75	6.25
65l-379	BW_R	2.87	0.00	0.00	0.00
65o-23	BW_R	16.67	5.00	13.75	6.67
65o-24	BW_R	3.19	0.53	32.45	31.91
65o-25	BW_R	5.85	0.98	4.39	3.41
	min	0	0	0	0
	5th	2.1551724	0	0	0
	25th	5.2235772	0.5130914	3.4530648	0.9820793
	75th	17.1875	5.0320513	14.206972	5.6833791
	95th	38.273366	16.887019	32.714227	17.02395
		41.666667	26.339286	33.516484	31.914894
		2	3	3	3
	D.E.	**0.5**	**0.75**	**0.75**	**0.75**

Appendix L						
Southeastern plain black water streams (Ecoregion 65)- Standardized Metrics and Final Index						
StationID	**Cond**	**Dip%**	**CrCh2Chi%**	**Tolr%**	**Dom01%**	**Oligo%**
65c-40	BW_I	23	100	98	64	100
65l-420	BW_I	4	84	44	87	98
65l-423	BW_I	67	100	0	73	0
65o-22	BW_I	10	77	92	56	29
65c-89	BW_R	9	100	89	77	94
HH24	BW_R	30	100	98	97	95
HH25	BW_R	49	100	94	87	100
HH26	BW_R	22	100	100	83	90
65g-82	BW_R	100	100	30	0	84
65g-83	BW_R	71	0	75	91	94
65h-202	BW_R	21	100	78	67	100
65h-206	BW_R	89	100	100	93	93
65h-209	BW_R	7	77	97	99	83
65l-10	BW_R	89	100	93	77	77
65l-342	BW_R	0	85	86	37	89
65l-343	BW_R	70	85	77	78	98
65l-379	BW_R	70	100	65	93	58
65o-23	BW_R	18	100	98	100	86
65o-24	BW_R	43	100	100	69	100
65o-25	BW_R	16	84	95	65	83

Appendix L- Continued (1)						
Southeastern plain black water streams (Ecoregion 65)- Standardized Metrics and Final Index						
StationID	**Cond**	**Oligo%**	**TolrTax**	**Dom01Ind**	**Filtr%**	**Trch%**
65c-40	BW_I	100	75	64	0	57
65l-420	BW_I	98	25	86	61	0
65l-423	BW_I	0	25	72	80	0
65o-22	BW_I	29	25	61	0	0
65c-89	BW_R	94	75	84	85	30
HH24	BW_R	95	75	98	26	100
HH25	BW_R	100	75	94	78	81
HH26	BW_R	90	100	90	97	25
65g-82	BW_R	84	50	0	100	0
65g-83	BW_R	94	0	95	72	45
65h-202	BW_R	100	25	75	76	15
65h-206	BW_R	93	100	95	75	0
65h-209	BW_R	83	75	100	85	3
65l-10	BW_R	77	50	78	86	26
65l-342	BW_R	89	50	36	84	7
65l-343	BW_R	98	0	77	80	15
65l-379	BW_R	58	25	99	99	0
65o-23	BW_R	86	75	100	58	30
65o-24	BW_R	100	100	79	25	3
65o-25	BW_R	83	50	72	20	6

Appendix L- Continued (2)						
Southeastern plain black water streams (Ecoregion 65)- Standardized Metrics and Final Index						
StationID	**Cond**	**Cole%**	**EPT%**	**Eph%**	**Prd%**	**EPTTax**
65c-40	BW_I	24	55	29	100	100
65l-420	BW_I	6	1	2	14	9
65l-423	BW_I	21	1	2	20	9
65o-22	BW_I	8	0	0	11	0
65c-89	BW_R	11	27	9	99	53
HH24	BW_R	10	89	8	49	98
HH25	BW_R	29	100	32	27	100
HH26	BW_R	29	21	9	100	62
65g-82	BW_R	0	0	0	0	0
65g-83	BW_R	90	26	6	37	44
65h-202	BW_R	36	48	71	37	53
65h-206	BW_R	100	13	24	65	18
65h-209	BW_R	5	4	5	35	18
65l-10	BW_R	35	23	15	23	62
65l-342	BW_R	7	4	0	9	27
65l-343	BW_R	12	27	37	26	44
65l-379	BW_R	12	0	0	8	0
65o-23	BW_R	31	42	39	44	62
65o-24	BW_R	0	99	100	8	44
65o-25	BW_R	17	13	20	15	27

Appendix L- Continued (3)							
Southeastern plain black water streams (Ecoregion 65)- Standardized Metrics and Final Index							
StationID	**Cond**	**TrchTax**	**Evenness**	**PrdTax**	**FiltTax**	**ClgrTax**	**Index**
65c-40	BW_1	100	100	100	100	100	83
65l-420	BW_1	0	100	61	43	13	44
65l-423	BW_1	0	100	41	43	6	41
65o-22	BW_1	0	100	41	86	26	38
65c-89	BW_R	43	100	95	71	71	67
HH24	BW_R	100	100	88	100	97	83
HH25	BW_R	100	100	54	86	100	85
HH26	BW_R	71	100	100	29	65	67
65g-82	BW_R	0	44	0	14	0	58
65g-83	BW_R	43	100	61	100	45	52
65h-202	BW_R	29	100	88	86	65	64
65h-206	BW_R	0	100	47	43	26	74
65h-209	BW_R	14	100	68	71	45	55
65l-10	BW_R	57	100	75	100	77	80
65l-342	BW_R	43	96	47	43	26	49
65l-343	BW_R	57	100	54	86	32	64
65l-379	BW_R	0	100	20	14	6	45
65o-23	BW_R	43	100	81	86	77	71
65o-24	BW_R	14	100	27	71	26	76
65o-25	BW_R	29	100	27	57	13	53
						25th	**55**
							12
							16
						DE	**75**

Appendix M						
Southeastern plain clear water streams (Ecoregion 65)- Metrics with a DE of 50% and Above						
StationID	**Condition**	**CrMolTax**	**AmphPct**	**OligoPct**	**BeckBI**	**ScrapTax**
65c-12	CW_Imp	0	0.83	0.00	11	2
65c-3	CW_Imp	1	0.00	1.69	1	5
65c-4	CW_Imp	3	0.00	3.52	0	3
65c-5	CW_Imp	4	0.85	4.68	2	4
65c-8	CW_Imp	1	0.00	0.00	4	2
65c-88	CW_Imp	0	0.00	0.46	1	1
65d-1	CW_Imp	3	0.00	11.67	0	2
65d-20	CW_Imp	0	0.00	0.00	7	0
65d-21	CW_Imp	3	0.42	0.42	6	3
65d-32	CW_Imp	0	0.00	0.00	6	2
65d-39	CW_Imp	2	0.00	0.42	9	4
65g-10	CW_Imp	3	1.67	17.50	2	3
65g-130	CW_Imp	1	0.00	10.14	0	1
65g-135	CW_Imp	0	0.00	5.29	0	0
65g-137	CW_Imp	0	0.00	8.18	1	0
65g-14	CW_Imp	3	0.48	19.32	0	2
65g-17	CW_Imp	4	0.42	12.66	2	5
65g-4	CW_Imp	2	4.55	20.13	0	2
65g-69	CW_Imp	4	0.00	5.00	1	2
65g-8	CW_Imp	1	0.00	9.66	0	1
65g-84	CW_Imp	2	8.00	24.44	0	1
65h-17	CW_Imp	1	16.67	5.42	3	2
65h-174	CW_Imp	0	1.67	1.25	6	2
65h-32	CW_Imp	3	16.46	11.39	0	3
65h-34	CW_Imp	1	0.42	3.75	2	2
65h-41	CW_Imp	1	18.23	2.60	5	2
65k-102	CW_Imp	0	10.00	0.45	1	4
65k-113	CW_Imp	1	12.39	0.46	1	2
65k-128	CW_Imp	0	2.23	0.45	1	1
65k-129	CW_Imp	5	0.42	8.75	1	3
65k-37	CW_Imp	0	6.37	0.49	1	2
65L-184	CW_Imp	1	10.00	3.33	3	2
65l-391	CW_Imp	2	22.08	4.17	0	3
65o-11	CW_Imp	2	12.67	8.60	1	1
65o-18	CW_Imp	0	0.00	18.58	1	1
65c-80	CW_Ref	3	2.08	2.08	3	5
65d-14	CW_Ref	0	0.00	0.00	6	2
65d-18	CW_Ref	4	1.67	0.42	5	4
65d-3	CW_Ref	1	3.33	0.42	2	2
65d-4	CW_Ref	0	0.00	0.47	5	1
65g-62	CW_Ref	3	10.00	2.92	4	4

Appendix M- Continued						
Southeastern plain clear water streams (Ecoregion 65)- Metrics with a DE of 50% and Above						
StationID	**Condition**	**CrMolTax**	**AmphPct**	**OligoPct**	**BeckBI**	**ScrapTax**
HH29	CW_Ref	4	1.85	1.39	4	8
65h-203	CW_Ref	2	0.00	0.42	0	5
65k-54	CW_Ref	3	0.98	11.71	2	4
65k-55	CW_Ref	3	0.85	0.00	3	5
65k-56	CW_Ref	4	10.98	0.00	0	3
65k-68	CW_Ref	3	10.82	0.00	0	3
65k-85	CW_Ref	3	3.02	10.05	2	3
65l-381	CW_Ref	1	8.86	1.69	4	2
65o-12	CW_Ref	3	1.36	0.00	1	3
	min	0	0	0	0	0
	5th	0	0	0	0	1.7
	25th	1.5	0.9151553	0	1.5	2.5
	50th	3	1.8518519	0.4166667	3	3
	75th	3	6.0970464	1.8855485	4	4.5
	95th	4	10.872117	10.547371	5.3	5.9
	max	5	22.083	24.444444	11	8
		21	22	22	21	24
		35	35	35	35	35
	DE	**0.6**	**0.6285714**	**0.6285714**	**0.6**	**0.6857143**

Appendix N							
Southeastern plain clear water streams (Ecoregion 65)—Standardized metrics and Final Index							
StationID	**Condition**	**CrMolTax**	**OligoPct**	**AmphPct**	**BeckBI**	**ScrapTax**	**Index**
65c-12	CW_Imp	100	100	8	100	34	68
65c-3	CW_Imp	80	93	0	19	85	55
65c-4	CW_Imp	40	86	0	0	51	35
65c-5	CW_Imp	20	81	8	38	68	43
65c-8	CW_Imp	80	100	0	75	34	58
65c-88	CW_Imp	100	98	0	19	17	47
65d-1	CW_Imp	40	52	0	0	34	25
65d-20	CW_Imp	100	100	0	100	0	60
65d-21	CW_Imp	40	98	4	100	51	59
65d-32	CW_Imp	100	100	0	100	34	67
65d-39	CW_Imp	60	98	0	100	68	65
65g-10	CW_Imp	40	28	15	38	51	34
65g-130	CW_Imp	80	59	0	0	17	31
65g-135	CW_Imp	100	78	0	0	0	36
65g-137	CW_Imp	100	67	0	19	0	37
65g-14	CW_Imp	40	21	4	0	34	20
65g-17	CW_Imp	20	48	4	38	85	39
65g-4	CW_Imp	60	18	42	0	34	31
65g-69	CW_Imp	20	80	0	19	34	30
65g-8	CW_Imp	80	60	0	0	17	31
65g-84	CW_Imp	60	0	74	0	17	30
65h-17	CW_Imp	80	78	100	57	34	70
65h-174	CW_Imp	100	95	15	100	34	69
65h-32	CW_Imp	40	53	100	0	51	49
65h-34	CW_Imp	80	85	4	38	34	48
65h-41	CW_Imp	80	89	100	94	34	80
65k-102	CW_Imp	100	98	92	19	68	75
65k-113	CW_Imp	80	98	100	100	34	82
65k-128	CW_Imp	100	98	21	19	17	51
65k-129	CW_Imp	0	64	100	19	51	47
65k-37	CW_Imp	100	98	59	19	34	62
65L-184	CW_Imp	80	86	92	57	34	70
65l-391	CW_Imp	60	83	100	0	51	59
65o-11	CW_Imp	60	65	100	19	17	52
65o-18	CW_Imp	100	24	100	19	17	52
65c-80	CW_Ref	40	91	100	57	85	75
65d-14	CW_Ref	100	100	0	100	34	67
65d-18	CW_Ref	20	98	15	94	68	59
65d-3	CW_Ref	80	98	31	38	34	56
65d-4	CW_Ref	100	98	0	94	17	62
65g-62	CW_Ref	40	88	92	75	68	73
HH29	CW_Ref	20	94	17	75	100	61

Appendix N-Continued--							
Southeastern plain clear water streams (Ecoregion 65)—Standardized metrics and Final Index							
StationID	**Condition**	**CrMolTax**	**OligoPct**	**AmphPct**	**BeckBI**	**ScrapTax**	**Index**
65h-203	CW_Ref	60	98	0	0	85	49
65k-54	CW_Ref	40	52	9	38	100	48
65k-55	CW_Ref	40	100	8	57	85	58
65k-56	CW_Ref	20	100	100	0	51	54
65k-68	CW_Ref	40	100	100	0	51	58
65k-85	CW_Ref	40	59	28	38	51	43
65l-381	CW_Ref	80	93	81	75	34	73
65o-12	CW_Ref	40	100	12	19	51	44
						25th	**51**
							11
							15
						DE	**73**

31	sites	Appendix O			
10	variable	Ecoregion 65 – Revitalized metrics			
	Q	Q	Q	Q	Q
	EPTTax	CrMolTax	AmphPct	DipPct	OligoPct
65c-89	0.030527	0	0	0.399199	0.007827
HH24	0.065085	0	0	0.383009	0.007924
HH25	0.075511	0	0	0.331917	0
HH26	0.04582	0	0	0.461017	0.017596
65g-82	0	0.008514	0.049665	0	0.017738
65g-83	0.032029	0.019217	0.003219	0.247863	0.009657
65h-202	0.033496	0	0	0.395562	0
65h-206	0.015634	0.039085	0	0.212538	0.014409
65h-209	0.010305	0.010305	0	0.411735	0.023528
65l-10	0.044993	0.019283	0.053563	0.177605	0.039468
65l-342	0.013806	0	0.005752	0.387324	0.013422
65l-343	0.031798	0.012719	0.15104	0.251733	0.00265
65l-379	0	0	0.085604	0.281269	0.077451
65o-23	0.043684	0	0.007801	0.455044	0.023236
65o-24	0.02723	0.010892	0	0.309962	0
65o-25	0.019048	0.006349	0	0.467692	0.027876
65c-80	0.071305	0.017826	0.012379	0.443178	0.012379
65d-14	0.09519	0	0	0.285133	0
65d-18	0.090502	0.025858	0.010774	0.393253	0.002694
65d-3	0.038277	0.006379	0.021265	0.41998	0.002658
65d-4	0.04049	0	0	0.229752	0.002703
65g-62	0.038501	0.016501	0.055002	0.029793	0.016042
HH29	0.110112	0.027528	0.012744	0.277191	0.009558
65h-203	0.034149	0.011383	0	0.384175	0.002371
65k-54	0	0.018793	0.006112	0.485879	0.07334
65k-55	0.08191	0.020477	0.005834	0.358793	0
65k-56	0	0.026756	0.073464	0.417582	0
65k-68	0.00406	0.012181	0.043951	0.261615	0
65k-85	0	0.011482	0.011539	0.00577	0.038465
65l-381	0.04526	0.005657	0.05013	0.436845	0.009549
65o-12	0.006145	0.018436	0.008342	0.350366	0

Appendix O- Continued..					
Southeastern coastal plain -Revitalized metrics					
	Q	Q	Q	Q	Q
	CrCh2Chi	TolerTax	BeckBI	ScrapTax	FiltrTax
65c-89	0	0.005088	0.010176	0.015263	0.025439
HH24	0	0.005917	0.023667	0.011834	0.047335
HH25	0	0.006293	0.062926	0.031463	0.037756
HH26	0	0	0.019637	0.032729	0.013091
65g-82	0	0.008514	0	0.004257	0.004257
65g-83	0.047102	0.025623	0	0.012812	0.051247
65h-202	0	0.016748	0.027914	0.016748	0.033496
65h-206	0	0	0.023451	0.039085	0.023451
65h-209	0.008833	0.005153	0	0.010305	0.025763
65l-10	0	0.012855	0.012855	0.019283	0.044993
65l-342	0.005085	0.009204	0	0.009204	0.013806
65l-343	0.006989	0.025438	0	0.019079	0.038157
65l-379	0	0.021279	0	0	0.007093
65o-23	0	0.006241	0.024962	0.018722	0.037444
65o-24	0	0	0.010892	0.016338	0.02723
65o-25	0.00747	0.012699	0.012699	0.006349	0.025398
65c-80	0	0.011884	0.017826	0.02971	0.035652
65d-14	0	0	0.035696	0.011899	0.017848
65d-18	0.010101	0.032322	0.032322	0.025858	0.045251
65d-3	0	0.031897	0.012759	0.012759	0.006379
65d-4	0	0.005784	0.028922	0.005784	0.011569
65g-62	0	0.027501	0.022001	0.022001	0.016501
HH29	0.00791	0.020646	0.027528	0.055056	0.027528
65h-203	0	0.011383	0	0.028457	0.03984
65k-54	0	0	0.012529	0.025058	0.006264
65k-55	0	0.006826	0.020477	0.034129	0.040955
65k-56	0.013513	0.013378	0	0.020067	0.040134
65k-68	0.003328	0.012181	0	0.012181	0.012181
65k-85	0	0	0.007654	0.011482	0.003827
65l-381	0	0.005657	0.02263	0.011315	0.050917
65o-12	0.117785	0.036872	0.006145	0.018436	0.049163